DRAFT FINAL

ACTION PLAN FOR THE CAMP EDWARDS IMPACT AREA GROUNDWATER QUALITY STUDY

MASSACHUSETTS MILITARY RESERVATION
CAPE COD, MASSACHUSETTS

Volume I - Text

Prepared for

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ARLINGTON, VIRGINIA

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THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, REGION I
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Prepared by

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List of Acronyms and Abbreviations

ABB	ABB Environmental Services, Inc.
AFCEE	Air Force Center for Environmental Excellence
ANG	Air National Guard
AOC	Area of Concern
APC	Armored Personnel Carrier
APR	Air Purifying Respirator
ARAR	Applicable, Relevant, and Appropriate Requirements
ARNG	Army National Guard
CDM	Camp Dresser and McKee
CLP	Contract Laboratory Procedure
CS	Chemical Spill
DO	Dissolved Oxygen
DNT	Dinitrotoluene
EMT	Emergency Medical Technician
EPA	Environmental Protection Agency
ERI	Environmental Research, Inc.
FID	Flame Ionization Detector
GP	Gun Position
HASP	Health and Safety Plan
HE	High explosive
HMX	Cyclotetramethylenetetranitramine
IDW	Investigation Derived Waste
IRP	Installation Restoration Program
kg	Kilogram
LITR	Light inexpensive training round
LRWSPAT	Long Range Water Supply Process Action Team
MAARNG	Massachusetts Army National Guard
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
mg	Milligram
MMR	Massachusetts Military Reservation
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAD27	North American Datum 1927
NGVD	National Geodetic Vertical Datum
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PID	Photoionization Detector
PPB	Parts Per Billion

PPE	Personal Protective Equipment
PPM	Parts Per Million
PRE	Preliminary Risk Evaluation
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
QAPP	Quality Assurance Project Plan
RAH	Risk Assessment Handbook
RDX	Cyclonite
SA	Site Assessment
SOP	Standard Operating Procedures
SVOC	Semi-Volatile Organic Compounds
TAL	Target Analyte List
TCL	Target Compound List
TNT	Trinitrotoluene
USACHPPM	United States Army Center for Health Promotion and Preventive Medicine
USAEHA	United States Army Environmental Hygiene Agency
USGS	United States Geologic Survey
UXO	Unexploded Ordnance
VA	Veterans Administration
VOC	Volatile Organic Compound
WHPA	Well Head Protection Area

1.0 INTRODUCTION

The Army National Guard fully intends to partner with the Environmental Protection Agency (EPA) and other federal agencies to ensure a thorough, scientifically sound investigation of the effects of military operations on the groundwater beneath the Impact Area. By working with the EPA, the Massachusetts Department of Environmental Protection (MADEP), local officials and the citizens of Cape Cod, the Army National Guard (ARNG) pledges to complete the investigation and take the necessary steps to protect the environment of Cape Cod while providing realistic training for our citizen soldiers.

1.1 Background

In July 1996 the National Guard Bureau (NGB) and the Massachusetts Army National Guard (MAARNG) were directed by the Deputy Undersecretary of Defense for Environmental Security [DUSD(ES)] to study the effects of military operations on the groundwater beneath the Impact Area. This study was in response to concerns raised by EPA Region I in a letter to DUSD(ES).

In August 1996 NGB assembled experts from the Army, the Air Force, the MAARNG, the Army Corps of Engineers, the Army Environmental Policy Institute, Air Force Center for Environmental Excellence, Army Environmental Center, the Army Center for Health Promotion and Preventative Medicine and Georgia Institute of Technology to create an action plan to complete the study. Engineering Technologies Associates, Inc. was retained to write the action plan in accordance with the guidance provided by the working group.

In October 1996 the MAARNG began working with the Long Range Water Supply Process Action Team (LRWSPAT) on the development of the action plan.

In December 1996 a rough draft of the action plan was presented to the EPA, MADEP, and members of the LRWSPAT, which includes the EPA, MADEP, the Cape Cod Commission (CCC), and the water districts of Bourne, Falmouth, Mashpee, and Sandwich. The goal of this comment period was to solicit their input in the further development of the action plan. NGB requested comments be returned by 15 January 1997 so a final draft could be released for public review in March or April.

In February 1997 the action plan was drastically changed to address the comments received from the EPA, MADEP, and other members of the LRWSPAT and a Response to Comments was written. On February 19, NGB and MAARNG arranged for explosives experts to brief the LRWSPAT. After this meeting, NGB and MAARNG met with EPA and MADEP. NGB and MAARNG agreed to complete and release the Response to Comments and a comment resolution workshop was scheduled for March 17, 1997. After the workshop the final draft plan would be released for public comment.

On February 27, 1997 EPA Region I released an Administrative Order directing the NGB to prepare the work plan, which had previously been submitted to the EPA, MADEP, CCC, and the LRWSPAT, for a comprehensive investigation of the groundwater beneath the Impact Area. The Administrative Order provides for complete EPA oversight and participation and establishes a citizens advisory committee to monitor the work.

On March 3, 1997 the Chief of National Guard Bureau met with EPA Region I and pledged the NGB's full cooperation and support. On March 7, 1997 NGB presented the concept of the action plan to the EPA, MADEP, and other members of the LRWSPAT and discussed comments received from the EPA, MADEP and the Cape Cod Commission. This discussion, along with the Administrative Order, guided the final development of the draft action plan, released to EPA, MADEP and the public on March 14, 1997.

1.2 Overview

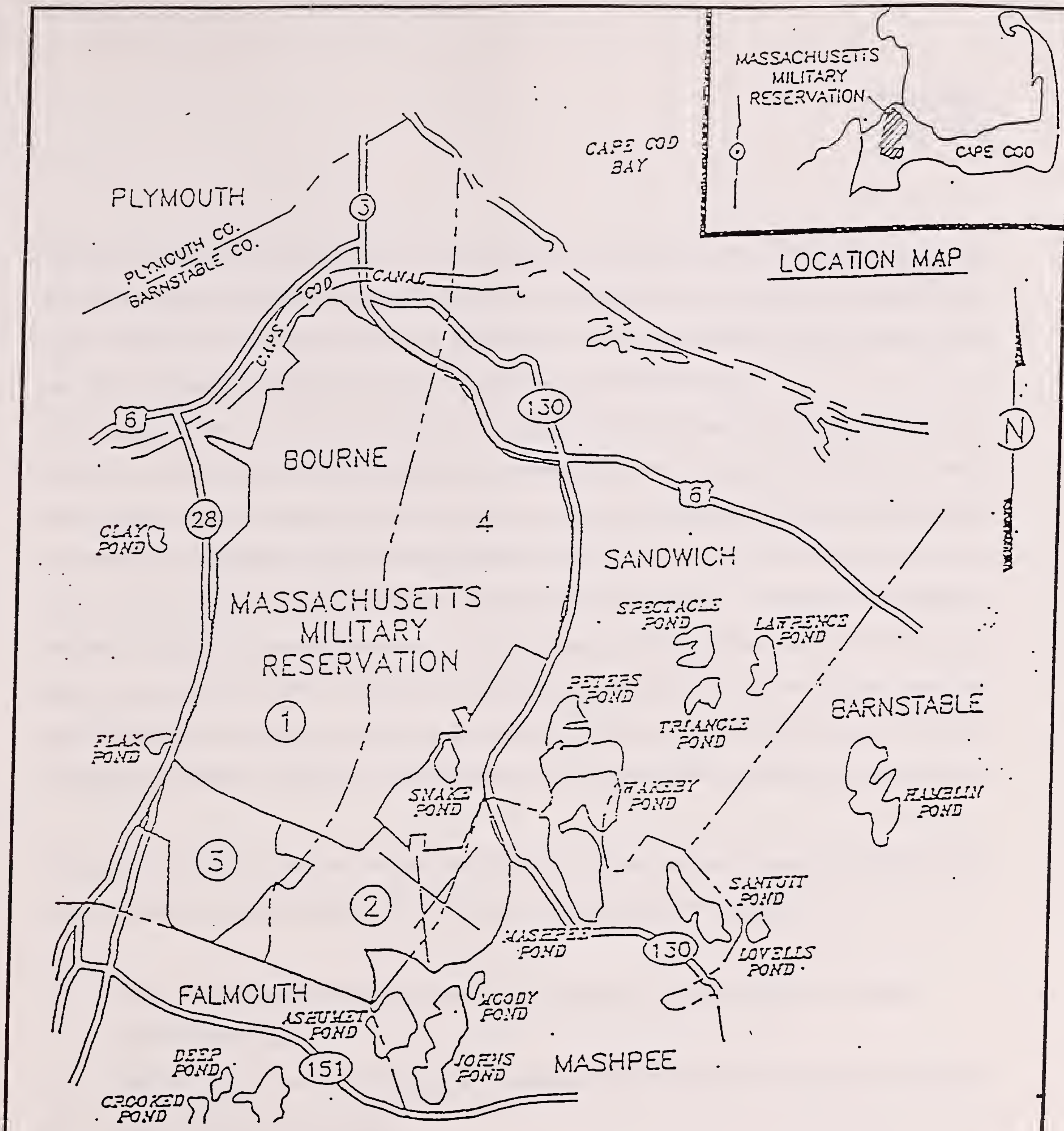
The Massachusetts Military Reservation (MMR) is a 21,000 acre facility located in western Cape Cod in the towns of Bourne, Falmouth, Mashpee and Sandwich in Barnstable County (Figure 1-1). The facility is organized into four functional areas:

(i) The Cantonment Area: The most actively used section, it consists of the base administrative, housing, maintenance and operation facilities (Area 2 on Figure 1-1);

(ii) The Training Range and Impact Area: Occupies most of the northern portion of the base, and is used for military training, law enforcement training and sport shooting (Area 1 on Figure 1-1);

(iii) The Veterans National Cemetery: Located in the southwestern corner of MMR, it contains a Veterans Administration (VA) Cemetery and support facilities (Area 3 on Figure 1-1), and

(iv) Cape Cod Air Force Station: Occupies the northeastern portion of the range area, and houses the air defense warning system (Area 4 on Figure 1-1).



LEGEND

1 RANGE MANEUVER AND IMPACT AREA
2 CANTONMENT AREA
3 MASSACHUSETTS NATIONAL CEMETERY
4 CAPE COD AIR FORCE STATION (PAVE-PAWS)

Source: Aneptek, 1995

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MMR IMPACT AREA WORKPLAN

FIGURE 1-1

MMR LOCATION MAP

Military use of MMR dates back to 1911, with the most intensive use of the facility occurring during and immediately after World War II. Most activities have been phased out to the current level consisting of the Otis Air National Guard Base airfield and military support facilities like the Veterans National Cemetery and the training range and Impact Area.
The training range and Impact Area has been used for Army National Guard, law enforcement and fire protection training. Law enforcement training consists of small arms firing at several ranges within the study area. The fire protection training involved training exercises with military and municipal fire fighters in the handling of brush and/or forest fires that results from the use of flares during military training exercises. Currently, the groundwater underneath the northern portion of MMR is being considered for development as potable water supplies for the four upper Cape towns of Bourne, Falmouth, Mashpee, and Sandwich. This action plan provides guidance and procedures for conducting fieldwork to gather data and information to determine the effects of military operations on the groundwater beneath the training range and Impact Area.

For more than 40 years, military and law enforcement training has been conducted in the training range and Impact Area at MMR. This training involves three distinct activities:

(i) Small arms firing at several ranges inside the study area, involving the use of small caliber munitions;

(ii) Artillery firing from gun and mortar locations into the Impact Area which is located in the center of the study area; and

(iii) Demolition ranges, one located to the north and just outside the study area; and another to the south of the Impact Area, located within a range inside the study area. The two demolition ranges are used to practice detonation procedures for explosives (see Figure 1-1).

1.3 Objectives of the Investigation

Working cooperatively with federal and state environmental agencies, the local authorities, the Long Range Water Supply Process Action Team (LRWSPAT), and the public on the Cape, the Army National Guard (ARNG) is conducting a study of the ground water quality beneath the training range and Impact Area at MMR. This study will determine whether the activities at the training range and Impact Area have affected, or will affect groundwater quality.

The study will include: a thorough review of the archives to investigate the types and volume of munitions used at MMR and determine the location of potential sources of contamination; the collection of data and information to verify the conceptual groundwater flow model and pattern in the training range and Impact Area; a preliminary investigation of suspected potential sources of contamination; human health and ecological risk assessments; and evaluation of the quality of groundwater beneath the study area. After a review of the data and as information becomes available, the scope of the investigation may be revised to include and adjust the number and location of investigation wells, conduct potential source investigations and aquifer characterizations to determine the long term effects of military operations on groundwater. The results of these investigations will be used to develop a long term monitoring program and the scope of the policy and/or technical response necessary to protect the quality of groundwater for the long term needs of the population on the Cape.

1.4 Environmental Concerns at the Training Range and Impact area

For more than 40 years, the training range and Impact Area at MMR has been used for military and law enforcement training. These training activities have been widely varied, as well as the size and types of munitions used. The impact of these activities and the fate of the spent munitions in the environment has been of interest for many parties on the Cape. The training and munitions used by activity and location are as follows:

(a) Small Arms Firing Ranges: These are outdoor pistol and rifle training ranges typically consisting of a firing position, a cleared range area, a target position, and an impact berm. Typically, the weapons that have been fired in these ranges are small caliber weapons including 50 caliber or smaller munitions; with the dominant choice being 5.56, 7.62 and 9 millimeter(mm) small arms rounds. The primary constituent of these munitions is a lead core in a metal alloy jacket, usually composed of copper, iron , and antimony.

(b) Artillery and Mortar Positions: These are small sites in the range area where the artillery and mortars are placed and fired at targets in the Impact Area. In the past, the spent shell casings and propellant bags were disposed of at these locations and/or in the vicinity of the artillery and mortar locations. The munitions used at these sites include 105 mm, 155 mm and 8 inch caliber artillery projectiles and 60 mm, 81 mm, and 4.2 inch mortar cartridges. The chemical constituents of these munitions are similar to those used at small arms ranges but also include explosive compounds.

(c) The Impact Area: This is the centrally located area in the range that contains the targets used for artillery and mortar firing. When the rounds fired are detonated, the explosive materials are generally consumed at the time of detonation. Sunlight degrades most of the remaining explosives. The metal shell casing breaks up into small pieces.

(d) Demolition Areas: These two locations are ranges that are used to practice detonation procedures for explosives. The environmental impacts associated with these ranges may be similar to the target areas in the Impact Area.

Explosives are defined as materials which have the potential to chemically change from a solid to a large volume of hot gases very quickly. High explosives (HE) are materials which undergo the

chemical change at a rate faster than the speed of sound, such as: TNT (trinitrotoluene), RDX (Cyclonite) , mercury fulminate, and lead azide. Low explosives undergo a chemical change at a slower than the speed of sound and include black powder, smokeless powder and other propellants. TNT has been the most widely used military explosive since World War I. RDX was developed during World War II, and is used in combination with TNT. Mercury fulminate and lead azide are used as primers in ammunition and are unstable.

The primary environmental interests associated with the historic, current and future use of the training range and Impact Area involve the metal projectiles from fired or "spent" munitions. The propellant is almost completely destroyed during firing, and while some propellant residues may accumulate at the firing point, the propellant itself is not likely to appear in the Impact Area. In the case of artillery firing, the excess propellant was burned after the firing, also in the immediate vicinity of the firing point. Artillery propellant bags are no longer burned at Camp Edwards. The HE rounds are composed of Composition B explosives, which are a combination of TNT and RDX. The projectile body is composed of forged steel. Most of the explosives in a HE projectile are destroyed at impact. Since 1985, only metal projectiles, not the live HE artillery rounds have been fired into the Impact Area at MMR for artillery training. Low cost indirect training rounds (LITR) are used in place of HE rounds for artillery training. The LITR rounds are manufactured with a combination of metals (Zinc, Potassium, and Aluminum). There are no explosives used in the artillery projectiles. Subsequently, in March 1997, the Army voluntarily stopped using HE mortar rounds. Currently, only inert short range training mortar rounds, with no high explosive content, are fired at MMR.

The HE in the current munitions used are designed to be completely consumed during firing and upon impact. Therefore, only the metal projectiles end up in the Impact Area. These metals are not very mobile, and numerous studies have shown that they are contained in the first six inches to two feet of the soils.

The investigation will include additional screening analysis to help determine if other military activities in the study area may have effected the quality of groundwater. The archives search will attempt to locate and review records of all activities that may have occurred in the study area in an effort to identify and investigate the use and handling practices for non explosive related hazardous materials (e.g. fuels, solvents, oils). The analytical program will be designed to analyze 30 percent of all samples collected for non munition related constituents.

1.5 Scope of the Action Plan

This action plan presents the technical and investigative aspects of the proposed study of groundwater quality beneath the training ranges and Impact Area at MMR as required by the administrative order.

The data gathered from this investigation will be used to modify the Pollution Prevention Plan also required by the Administrative Order. The Pollution Prevention Plan will determine the techniques and technologies available to prevent contamination resulting from military training activities.

2.0 BACKGROUND AND ENVIRONMENTAL SETTING

2.1 Site Location and History

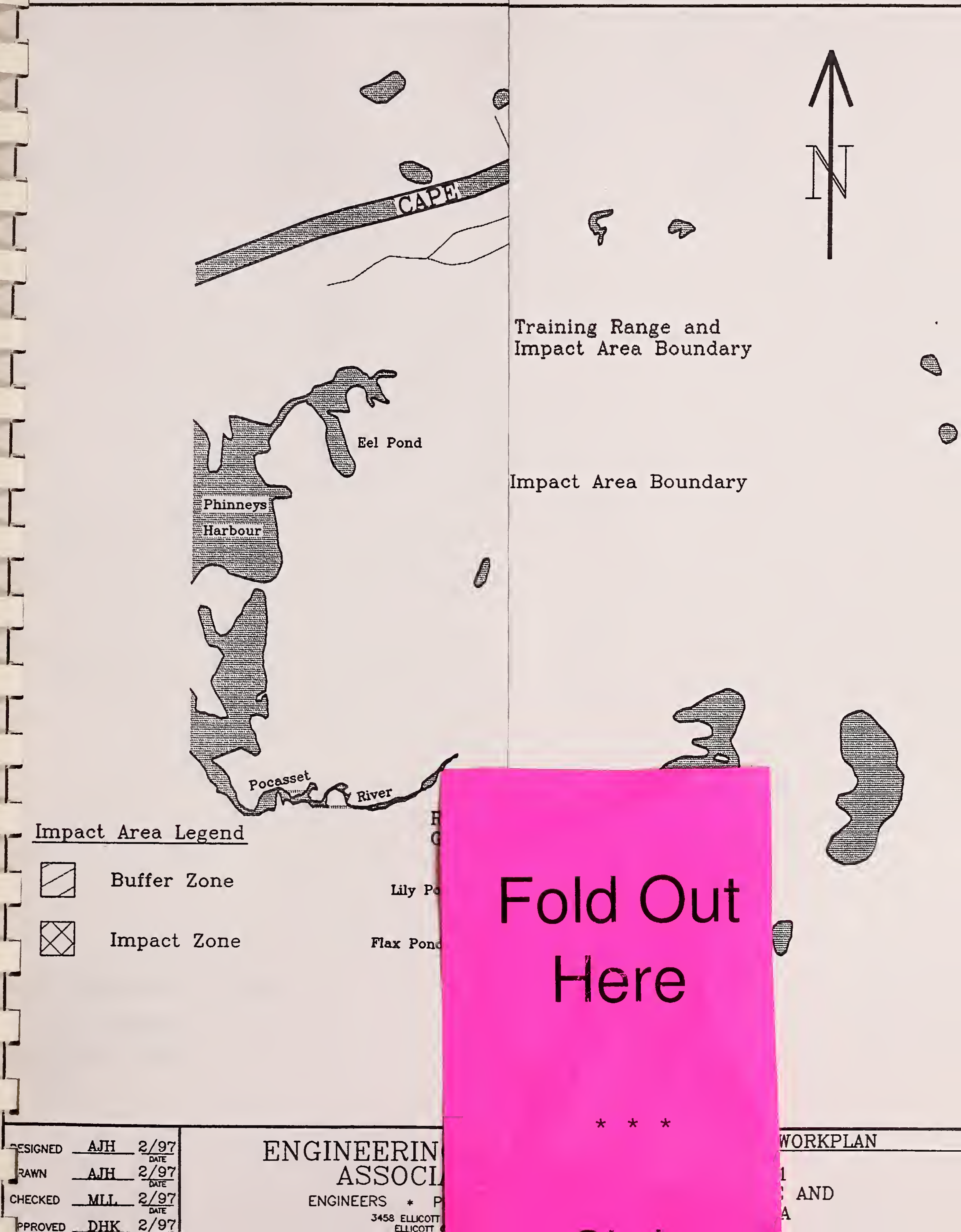
The MMR is located on upper Cape Cod, approximately 60 miles southeast of Boston, Massachusetts (See Figure 1-1). The MMR consists of approximately 21,000 acres. Approximately 14,000 acres, occupying the northern seventy percent of MMR, constitutes the training range and Impact Area (Figure 2-1). The primary focus of this investigation is the Impact Area. A secondary focus is the small arms ranges, demolition ranges, artillery and mortar firing positions surrounding the Impact Area, and the Rod and Gun Club to the southwest of the study area (Figure 2-2).

For over 40 years, MMR has been used for military and law enforcement training. This training has included the firing of small arms, guns, hand grenades, artillery, mortar and ordnance demolition. The environmental interests associated with these activities could potentially affect groundwater.

2.2 Site Description

The training range and Impact Area is in the central portion of MMR. Numerous firing ranges, artillery and mortar positions, and training areas surround an Impact Area in the center of the study area (See Figure 2-2).

The Impact Area contains targets at which artillery and mortars are fired during training activities. The primary target area is the strip along the road in the southeast and central portions of the Impact Area referred to as "tank alley." (Tank alley is a row of metal tank hulls used as targets.) The northern portion of the Impact Area around the intersection of Woods, Turpentine and Sandwich roads (also known as the "five corners" area) used to be, but is no longer a target area. The Impact Area includes a 500 meter buffer zone around the target areas (See Figure 2-2).



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Source: Analysas, 1995 and US Defense Mapping Topo Maps

MMR IMPACT AREA WORKPLAN

FIGURE 2-1
TRAINING RANGE AND IMPACT AREA

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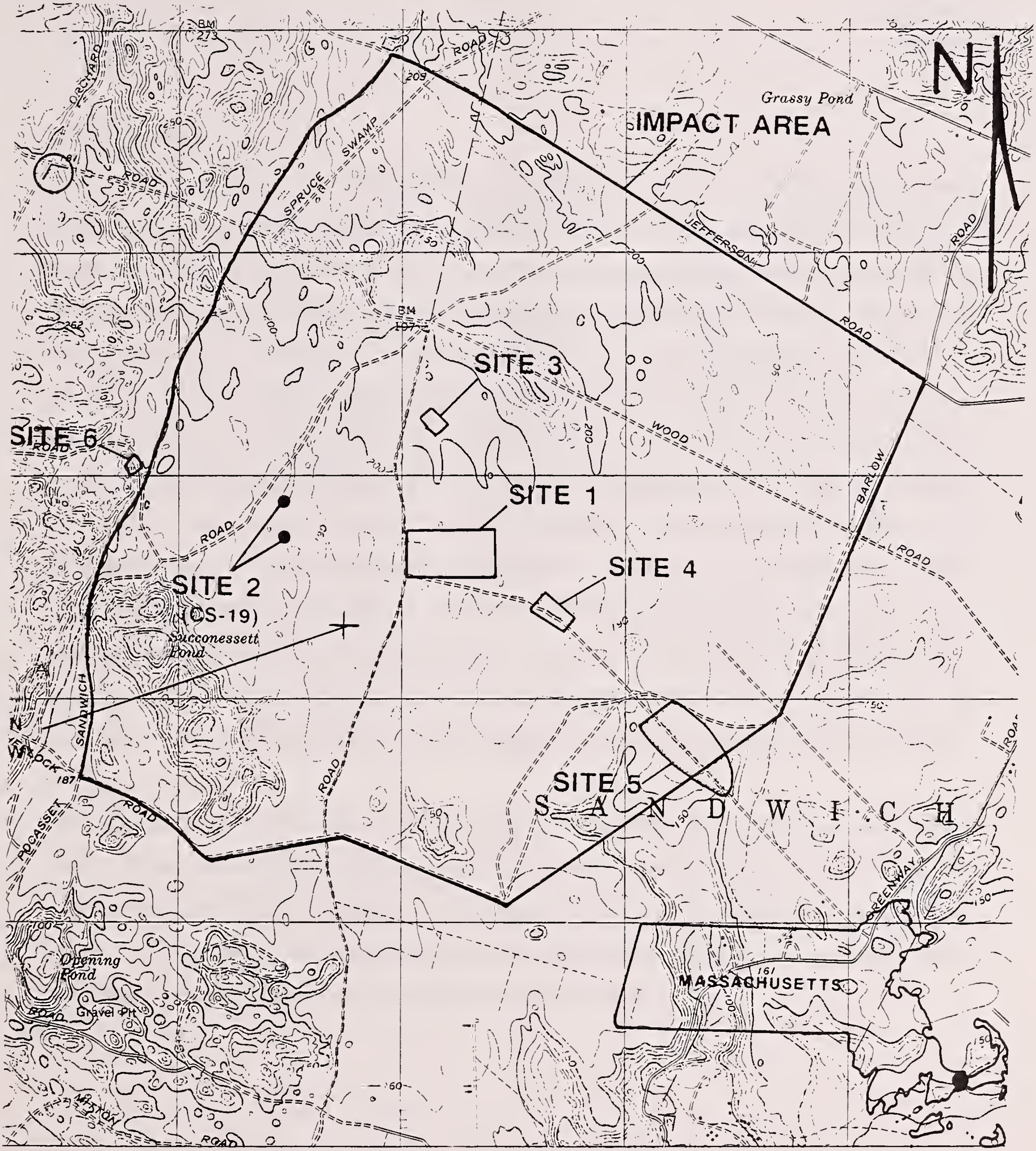
The study area will be the training range and Impact Area located inside of Pocasset Forestdale Road, Burgoyne Road and Gibbs Road, the demolition areas and the Rod and Gun Club (Figure 2-2).

2.2.1 Physiography and Surface Waters

The Cape Cod peninsula was formed during the retreat of the glaciers at the end of the Ice Age. It consists of two distinct types of terrain resulting from the recession of two separate lobes of ice sheets. The training range and Impact Area are located on a broad, undulating glacial outwash plain with considerably more relief than the area to the south. The elevation generally ranges from 100 to 250 feet with the highest reported elevation of 306 feet above mean sea level (Massachusetts ARNG, 1985). The training range Impact Area is dotted with natural depressions called "kettle holes". Only one of these kettle holes, Succonsette Pond, which is located in the southwestern corner of the Impact Area buffer zone, contains water (Figure 2-3).

Due to the high permeability of the sands and gravel underlying the training range and Impact Area, there are no perennial streams, and very little to no run-off. This suggests that almost all precipitation in the training range and Impact Area ends up as groundwater recharge or evapotranspiration. The rapid infiltration of rainfall essentially eliminates surface water runoff and ponding - even in most kettle holes. Intermittent streams are only visible in a few drainage swales, and are only active during heavy rainfall. Succonsette Pond appears to be fed from groundwater flow-through, and run-off waters during heavy rainfall events. It has no surface water outflow. Topography of the range shows swales leading out of the Impact Area; others terminate within the range (USGS, 1976).



Source: ERI Report, 1994

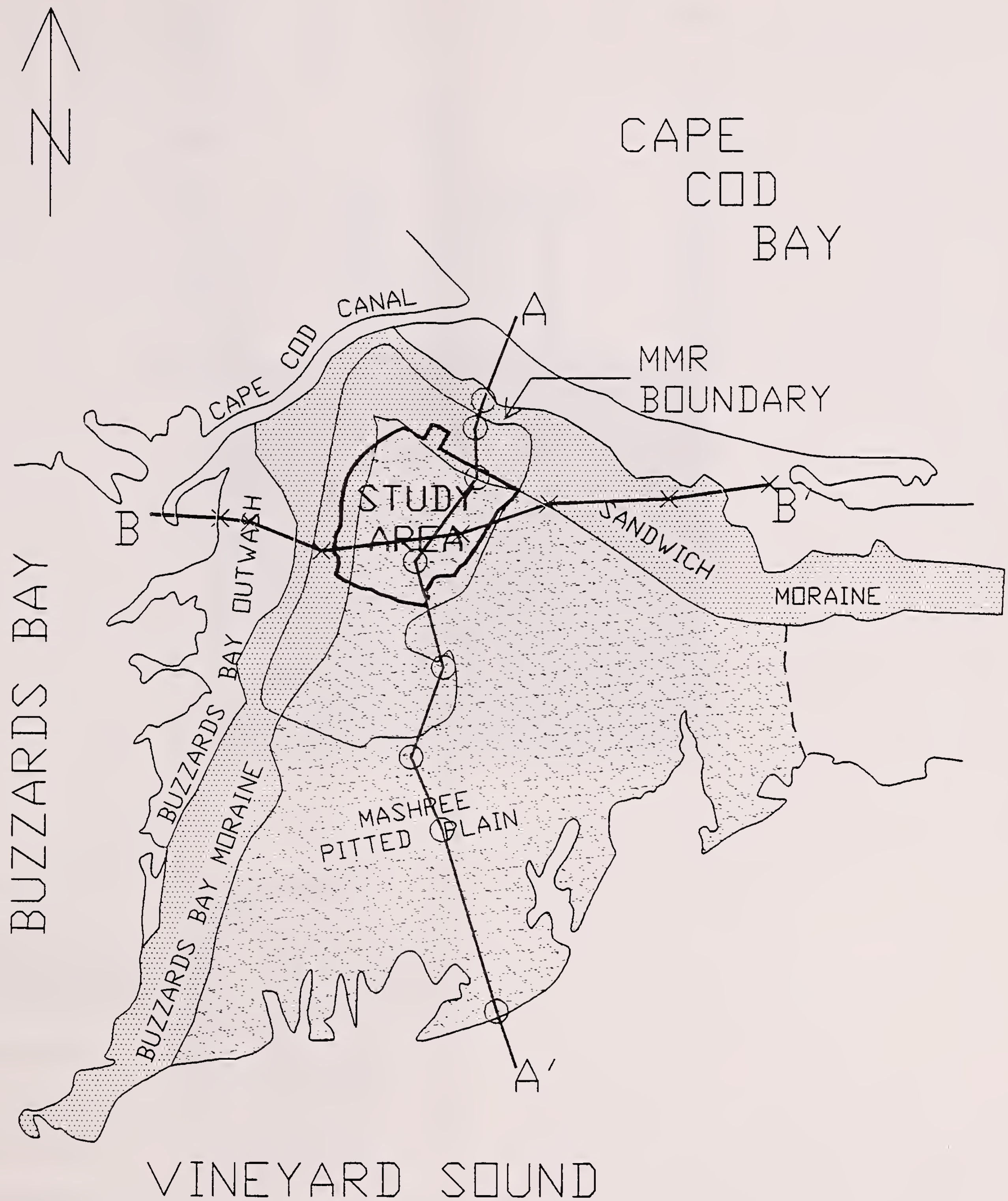
FIGURE 2-3

DESIGNED ____ DATE DRAWN ____ DATE CHECKED ____ DATE APPROVED ____ DATE	ENGINEERING TECHNOLOGIES ASSOCIATES, INC. ENGINEERS • PLANNERS • SURVEYORS	PHYSIOGRAPHIC MAP OF THE TRAINING RANGE AND IMPACT AREA SCALE: CONTRACT NO.: DATE: SHEET

2.2.2 Geology

MMR is located within the Coastal Plain physiographic province. The predominant physical features are moraines and outwash plains composed of poorly sorted, heterogeneous mixtures of sands, silts, gravel, and boulders mixed with well sorted and stratified sands, gravel and silt. These geomorphologic features are a result of depositional processes associated with the advance and retreat of two ice sheets. Three distinct geologic units can be identified: the Sandwich Moraine in the north, the Mashpee Pitted Plain in the southeast, and the Buzzard Bay Moraine in the west (Figure 2-4). The training range and Impact Area is located on the north-central portion of MMR, which is underlain primarily by the Mashpee outwash plain. The geology is comprised of stratified, unconsolidated sands and gravels underlain by crystalline bedrock. Figure 2-5 is a north-south and east-west geologic cross section of the study area as depicted on the USGS Hydrogeologic Framework of Western Cape Cod, 1997. This hydrogeologic framework is based on the depositional history of the sediments of the region. The surface elevations typically vary between 100 and 140 feet above MSL in the outwash plains to about 300 feet above MSL in the moraines. The crystalline bedrock is at an average elevation of 150 feet below MSL (USAEHA, 1986).

The surface and subsurface soils are characterized by a heterogeneous mixture of cobbles, gravel, sand, silt and clay to highly stratified sands and gravel. Typical of these soils are fine loamy topsoil overlying thick sand deposits or silty materials over stratified sand and gravel. All these deposits sit on a bedrock that has been mapped as a granodiorite (USGS, 1976). Radon and the resulting radiation is common in Massachusetts granitic bedrock.



Source: Aneptek, 1995

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Source: Analysas, 1995 and US Defense Mapping Topo Maps

MMR IMPACT AREA WORKPLAN

FIGURE 2-2
GUN AND MORTAR POSITIONS, RANGES, AND IMPACT AREA

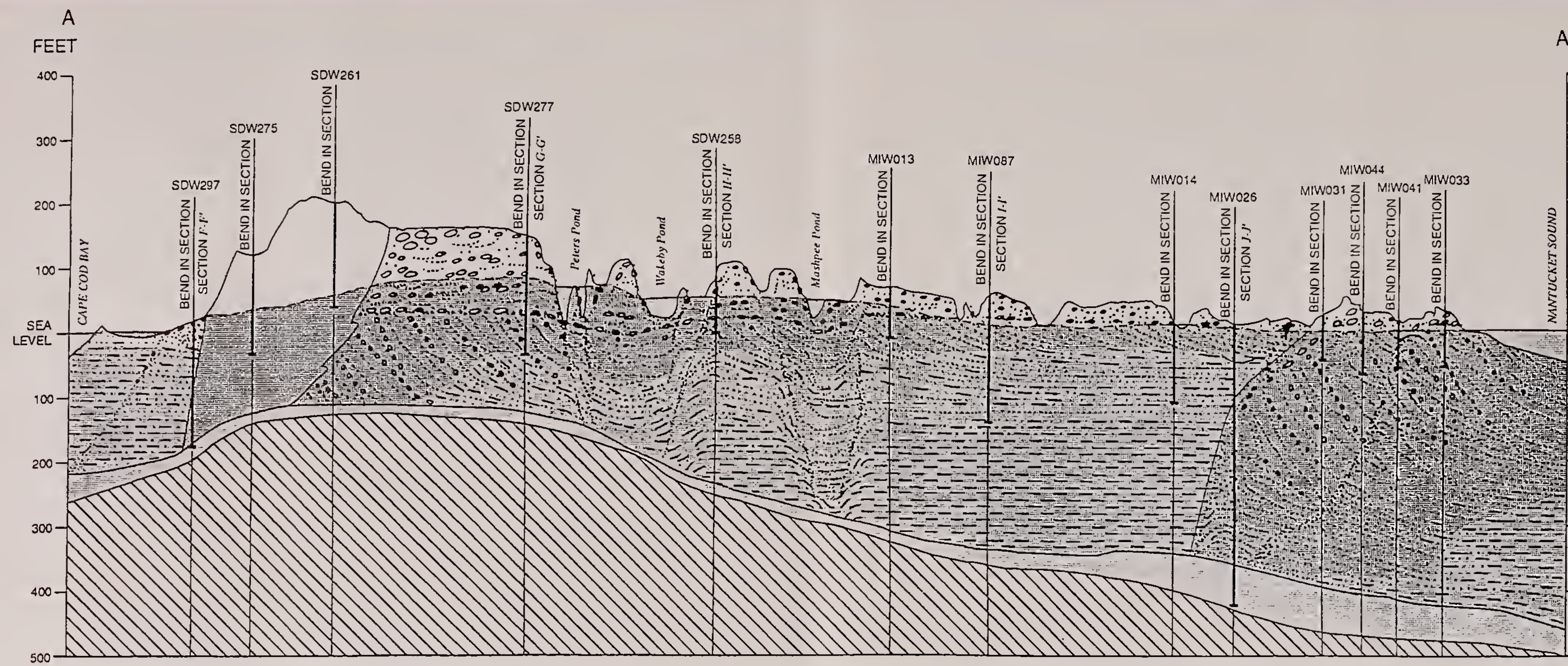
SCALE: | CONTRACT NO.: 92307.012 | DATE: 2/97

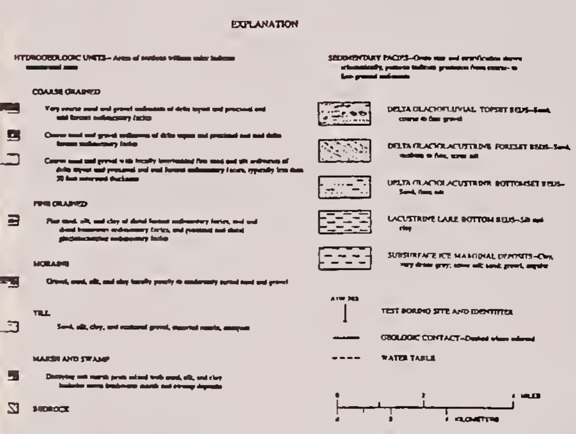
2.2.3 Hydrogeology

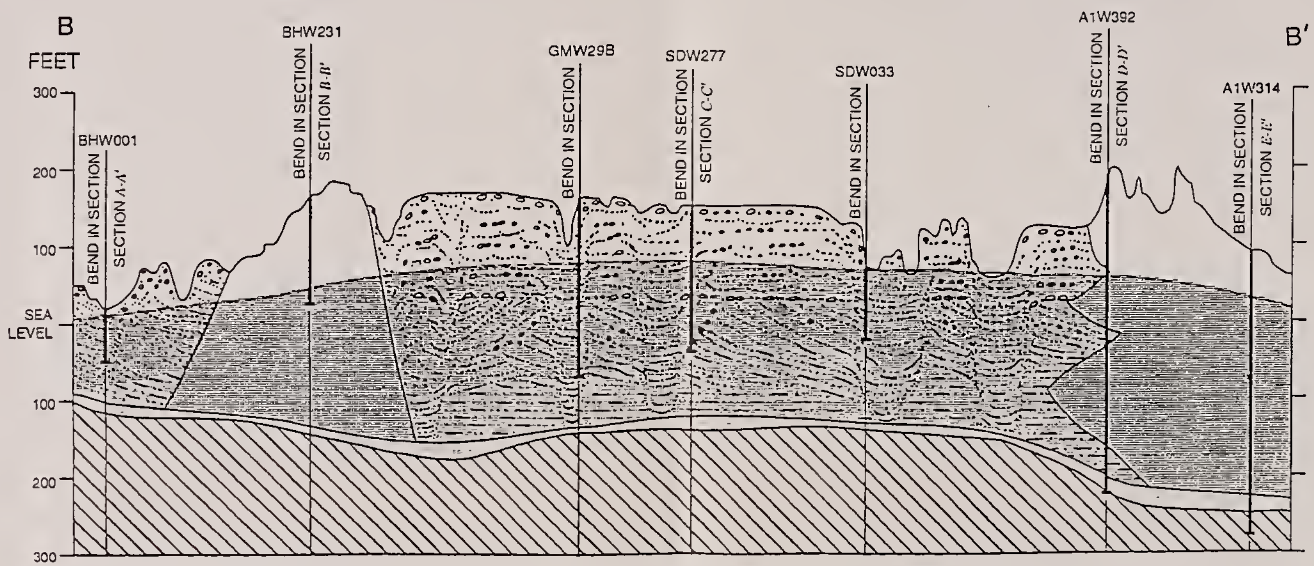
The aquifer beneath MMR is part of the unconsolidated glacial deposits of Cape Cod, which constitutes the primary and sole source of potable water. The groundwater is under unconfined conditions with the highest groundwater surface elevations beneath the MMR. Therefore, groundwater flows radially in all directions from the Reservation (Figure 2-6).

The training range and Impact Area is a major recharge area. The apex of the groundwater system is southeast of the Impact Zone. The direction of groundwater flow is between west southwest and north northeast.

Recharge to the aquifer is from precipitation, averaging about 21 inches a year. The depth to groundwater can be as deep as 140 feet (ABB, 1992) in areas of high elevations in the training range and Impact Area, and has been documented to be about 115 feet at the IRP CS-19 study area in the Impact Area (USACHPPM, 1996). Based on the predicted water table elevation (see Figure 2-6), the average depth to groundwater in the Impact Zone is 110 feet with less than one percent of the water table within 50 feet of the land surface. The unconsolidated sands and gravels are highly permeable with hydraulic conductivities between 200 and 300 feet per day. With average groundwater gradients of 0.003 percent, the groundwater flow velocity probably ranges between 0.8 to 2.3 feet per day (ft/d) (USGS, 1976). The vertical hydraulic conductivity appears to be relatively high, but lower than the horizontal. Data are limited on this subject, and the extent of anisotropy within the aquifer has not been defined.







Source: USGS, 1997

FIGURE 2-5

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MMR IMPACT AREA WORKPLAN

Geologic Cross Sections of the Study Area

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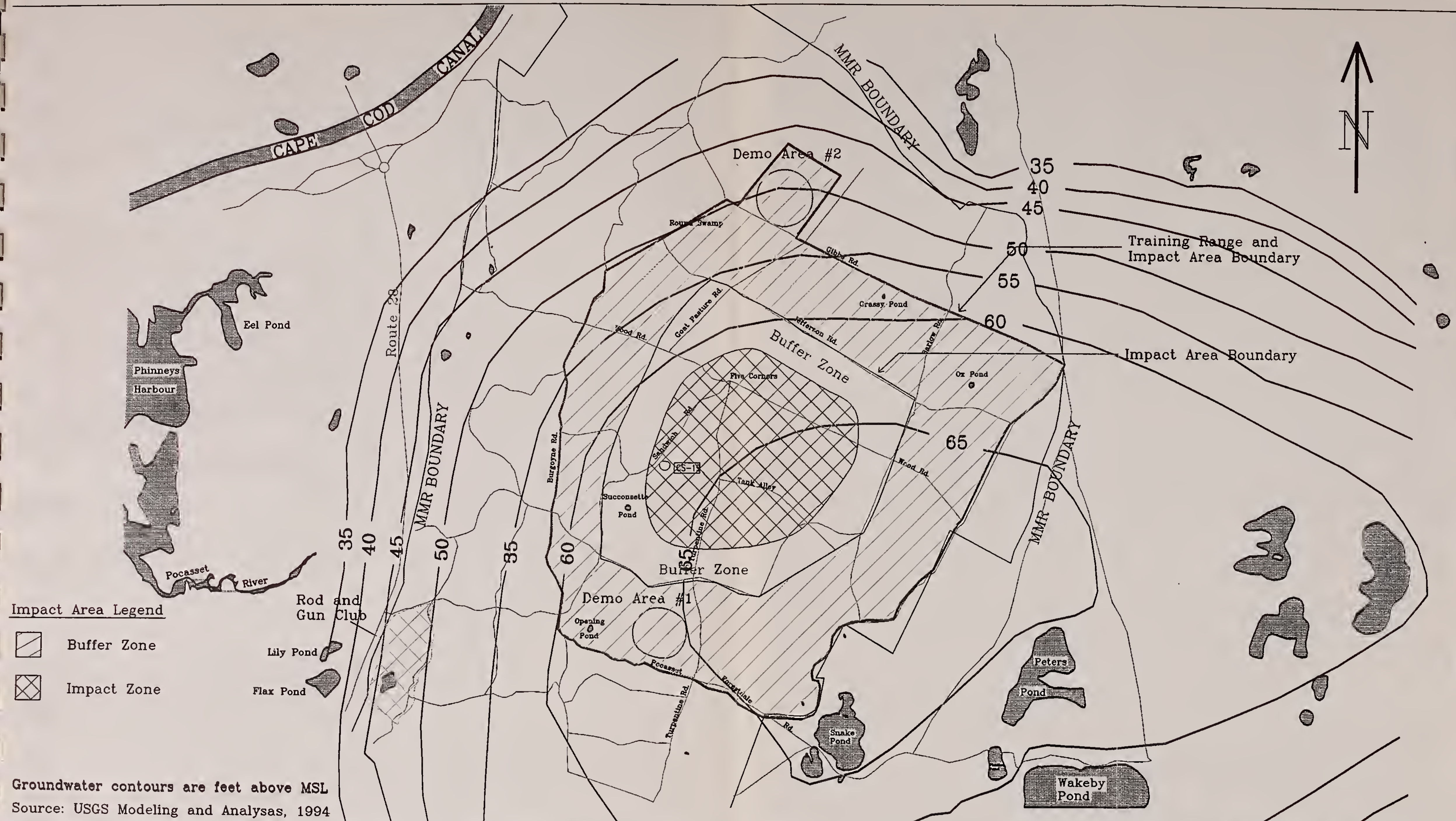
2.3 Previous Investigations

The study area covers the north-central portion of the installation; and consists of a central Impact Zone surrounded by a buffer zone, and both surrounded by numerous ranges (see Figure 2-2). Small arms training and target shooting are conducted at the ranges, while artillery and mortar fire originate from gun and mortar positions in some of the ranges unto targets located in the Impact Zone. Over the life of the installation, other potential sources (e.g. FS-12, FS-14, CS-1) have been identified in close proximity to the Impact Area (Figure 2-7), and these have been investigated by the IRP. Some of these studies have included the following:

In 1987, the U.S. Army Environmental Hygiene Agency (USAEHA) conducted an investigation of ash remains from the burning of propellant bags at artillery and mortar positions. The scope of this study was limited to determining soil contamination from the ash remains. Two gun positions (GP-8 and GP-9), were selected as representative sites. These sites were investigated as Area of Concern-Chemical Spill -18 (AOC CS-18) under the Installation Restoration Program (IRP). Soil samples were collected from the top 18 inches at burn locations and analyzed for volatile and semi-volatile organics, heavy metals, and explosives. Some of these analytes were detected, but at acceptable levels for the current land use when compared to background levels, except for lead. Due to the fast decline in concentration levels with depth (90% decline within 6 inches of surface), the relative immobility of lead, and the depth to groundwater, the report concluded that the soils were not hazardous, and not an imminent source for environmental concerns. However, the report recommended further investigations. This was due to the lack of specific regulations for contamination from explosives, the potential for change in the regulations, and the limitations of the laboratory techniques available at the time for detecting explosive compounds.



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MMR IMPACT AREA WORKPLAN
FIGURE 2-6
GROUNDWATER ELEVATION CONTOURS

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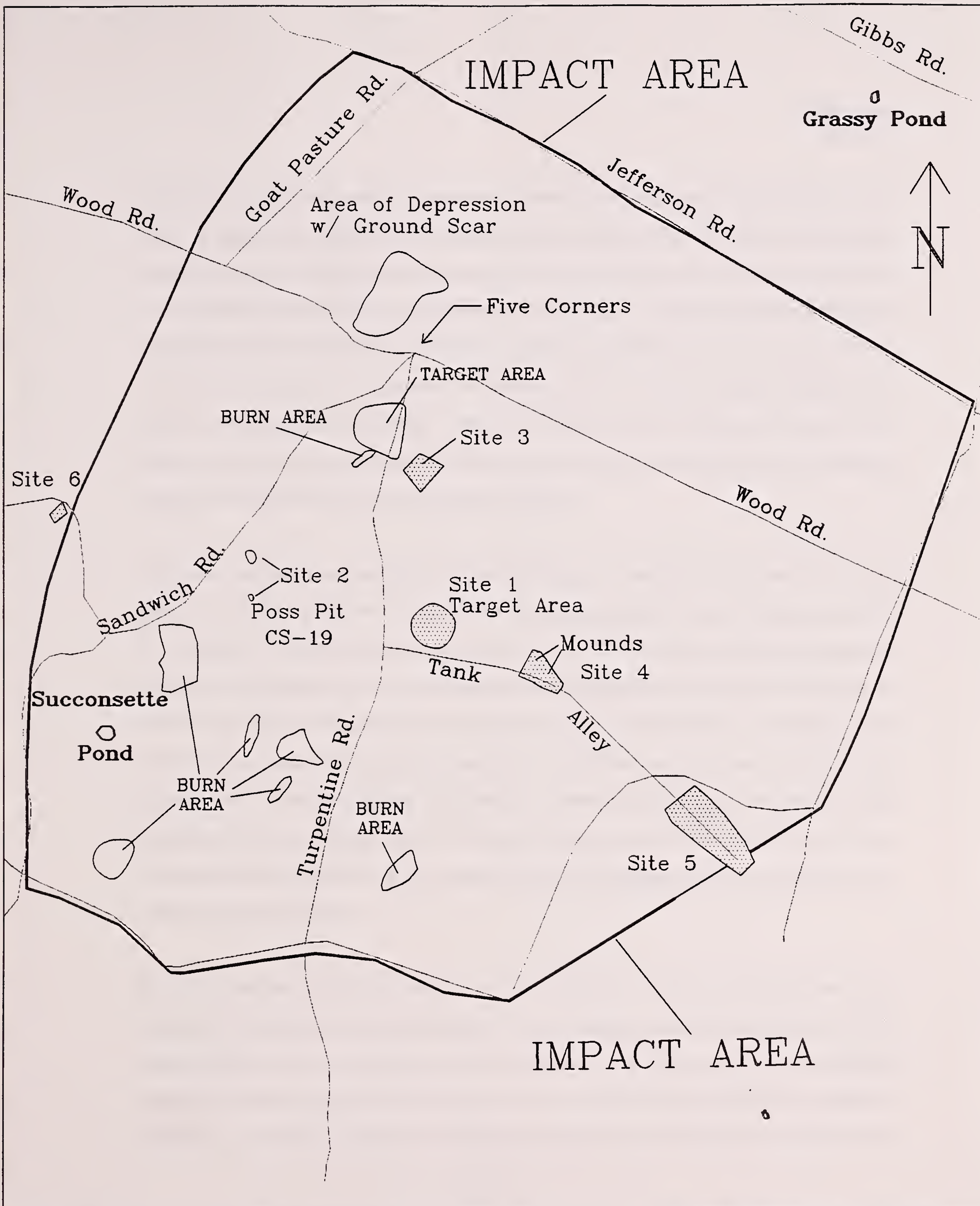
In 1994, the U. S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) conducted a follow-on study of the effects of burning propellant bags at two firing positions, GP-8 and GP-9. This study was a detailed investigation of the firing locations, and included soil and groundwater sampling. Soil samples were analyzed for heavy metals, explosives, and semi-volatile organic compounds (SVOCs). Groundwater samples were analyzed for volatile organic compounds (VOCs). The results of this investigation showed some explosives and heavy metals, mostly in the top one foot of soil. A preliminary risk evaluation (PRE) was conducted using these results. The study concluded there was no imminent danger to human health, and no current or expected threat of ecological risk exists from current or continued use of the sites.

Also in 1994, an aerial photographic site analysis (ERI, 1994) was conducted using aerial photographs dating back to 1943. This study covered the whole training range and Impact Area in an effort to identify other sites suspected to be potential sources of past contamination. The analysis was conducted by viewing illuminated transparencies of aerial photos through a stereoscope. Stereoscopic magnification and viewing enables the analyst to identify characteristics associated with different environmental conditions based on color, texture, tone, shape, size and patterns associations. These characteristics allow specific objects and/or conditions to be recognized, and associated with specific activities and sites.

Six sites were clearly identifiable (Figure 2-8), with numerous areas showing varying levels of activity. Some of these areas went through several clearing and revegetation cycles between 1943 and 1991. Several ground scars, which are evidence of burning, were identified over the years, and the primary target areas showed small impact craters throughout the period studied (ERI, 1994). The nature and conditions of these sites are as follows:



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MMR IMPACT AREA STUDY
FIGURE 2-8
AREAS of INTEREST
BASED on AERIAL PHOTOGRAPHS

SCALE: CONTRACT NO.: DATE: SHEET:

1. Site #1 is a circular target area located along Turpentine Road that was first noted in a 1951 photo. It appears to have served as a burning ground with multi-toned, darker soils than the surrounding areas. Piles of materials were noticed on the 1951 photo, but had disappeared by 1958 and the area seemed to have been mechanical cleared. By 1963, the area appears to revegetating. In a 1971 photo, all activities at this location seemed to have stopped. From 1971, the area at Site #1 continued to revegetate until it was no longer distinguishable, except for the shells of old tanks in a row to the south of the site. However, between 1977 and 1991, the area was once again used heavily as an Impact Area judging from the impact craters and the tank shells, presumably used as targets.

2. Site #2 is otherwise known as CS-19 in the IRP Program. This site first appeared in a 1958 photo as a bunker with the area around it cleared; and a small trench was visible to the north of the bunker. A second clearing was located about 600 feet to the south of the bunker at the end of what appeared to be a new access road. Through the years until 1963, the bunker and clearing were visible, but the trench did not exist in a 1963 photo. No changes were observed in the conditions of the site until 1977 when three new pits were noticed in the northern area. These pits had liquid in them. A review of hydrologic data for the week preceding the photo indicated that 3.39 inches of rainfall was recorded that week. These two sites were still visible in a 1991 photo, with what appears to be a pit located at the entrance to the access road.

3. Site #3 is another target area which was first noticed in 1951 as a ground scar and topographic depression, but developed into a second Impact Area which seemed to have become active about the same time (1958) as Site #1. New ground scaring and impact craters were visible to the north and south of the five corners area bothering the topographic depression. In addition, numerous fires were burning at this time (April 30, 1958) to the

south of the area. By 1963, the target area had shifted first to the south of Five Corners and then to a new area to the east of Turpentine Road and about 1800 feet south, southeast of Five Corners. This new target area had three trenches along the borders of the target, two antenna in the center and a viewing towers at the northeast boundary. The area appeared to be revegetating in a 1965 photo, but the trenches were still in place. This target area appears to have been used throughout its existence, up till the present. There seem to have been some earth-moving work done at the site in 1985, and the unvegetated areas are still unvegetated.

4. Site #4 first appeared in a 1963 photo, and consisted of a pile of soil and rubble. This pile appeared to be associated with, and is part of the construction of "J" Range located to the Southeast. This pile has existed since then, and continues to grow as more rubble (including old armored vehicles) is added to the pile. In 1970, a new access road was constructed from the pile to the target area (site #1) and armored vehicle shells placed along the road. In 1971, a topographic depression which contained water, was observed near the pile. A review of rainfall data indicated a total of 1.42 inches of rain in the previous week. The mound of dirt and rubble was still visible in 1977, but no standing water or depression was visible. The armored vehicle shells are in the same locations. By 1991, a second mound is visible on site and both mounds appear to have been used to store dirt used to construct the backstop for the "J" Range.

5. Site #5 is the "J" Range; also known as the Textron Site. This range existed before 1966 when it was enlarged and first appeared in an air photo. A new portion was under construction in 1970 and a large area was cleared. In 1971, two trenches were clearly visible in the northwestern portion of the site, and the site was dotted by earth moving equipment. Over the next few years, numerous trenches were dug for backstop materials

until 1977 when all but one of the trenches was visible. The mounds of dirt and a partially filled trench are still present. The cleared area is also much longer than in the 1975/1976 photo. By 1985 and certainly by 1991, all the old trenches and debris are gone from the site. A new trench is present in the southeastern end of the range; with a pile of dirt at the northern end of the trench.

6. Site #6, a vehicle and supplies staging area, first appeared in a 1970 photo as a cleared and disturbed area adjacent to the western boundary of the Impact Area on Monument Beach Road. This site seems to have been cleared and graded as a storage area for bulk supplies and support vehicles. This area seems to have been used between 1970 and 1985. By 1991, the use of the site had been suspended, and the area seems to be revegetating.

In addition to these six sites, there are five other areas in close proximity to the site; including the FS-12, FS-14, USGS-CS-1, CS-18 and LF-3 sites which have all been investigated by the IRP. The following are a brief summary of the findings, and the current status of these sites.

1. The FS-12 site is a known jet fuel spill site dating back to the early 1970s. The site has been investigated and is currently being remediated under the IRP. The site is located near the apex of the groundwater recharge area.

2. FS-14 is an IRP site located to the north of the study area. It was the site of a 500-gallon gasoline spill in 1985. Contaminated soils were excavated and removed from the site the very next day. In 1992, the site was identified in a Preliminary Assessment (PA), and a Site Inspection (SI) conducted in 1996. This SI consisted of soils and groundwater sampling and analysis. No gasoline components were detected in any of the samples collected and

therefore, a no further action decision is being required of the EPA by the IRP. FS-14 is downgradient of the study area.

3. USCG-CS-1 was a suspected solvent spill area consisting of several smaller sites including a former drummed hazardous waste storage area in the transmitting building, a buried fuel line, a 4,000-gallon above ground fuel storage tank, a storage building, an illegal dump site to the east of the transmitting building, and a magnetic anomaly to the west of the transmitting building. Review of historical documents indicated that small amounts of solvents were disposed of at scattered locations around the transmitter building. The SI and RI conducted at the site did not identify any hazardous contaminants, but did detect compounds associated with normal lawn maintenance. The concentrations of most of the compounds detected, including PCB, xylenes, PAHs, Chromium, Lead and Mercury were estimated, and were detected below the detection limits. Shallow groundwater samples collected from seven wells contained trace amounts of TCE, 1,1,1-TCA, and chloroform; and these levels were not traced to any particular source. Deeper groundwater monitoring via annual sampling (20 feet below water table) and analysis has provided results showing all contaminant levels to be below MCLs. Monitoring stopped in 1993 with a record of decision document to the EPA.

4. CS-18 is also known as Gun Position-9 (GP-9) which was investigated as a worse case representatives of all the gun positions based on the volume and frequency of use. The investigation included soils and groundwater sampling and analysis. Soil samples were collected from surface to the water table, and monitoring wells installed and sampled. Results indicate that soil contamination from explosives is limited to the top 18 inches of soil, and that the groundwater has not been affected by the activities at this site.

5. LF-3, located on the northeastern boundary of the MMR and to the northeast of the Impact Area, was a one time incident when somebody illegal dumped household materials including old furniture and construction debris. Upon discovery in 1995, the junk was removed and properly disposed of at the main base landfill (LF-1). The site was closed under the IRP program.

Under the IRP, a site investigation was conducted at the CS-19 location, identified as site #2 in the ERI study, within the Impact Area in 1992. This investigation included personnel interviews, geophysical surveys, and soil sampling. Soil samples were collected and analyzed for heavy metals, VOCs, SVOCs, herbicides, and polychlorinated biphenyls (PCBs). The geophysical surveys indicated that nearly all the identifiable anomalies were attributable to surface or subsurface metallic debris. The results of the laboratory analysis of soil samples indicated the presence of several organic and inorganic chemicals. The organics included one explosive compound, HMX (Cyclotetramethylene-tetranitramine), some pesticides including endrin ketone, alpha-BHC, heptachlor, 4,4-dichloro-diphenyldichloroethylene (DDE) and 4,4-dichlorodiphenyldichloroethane (DDD), endosulfan sulfate; some herbicides, dioxins, and furans. Inorganic chemicals detected included aluminum, chromium, copper, iron, lead, magnesium, manganese, mercury, vanadium, nickel, arsenic, barium, beryllium, cadmium, calcium, potassium, silver and zinc. Most of these compounds were detected in samples taken from surface to 3 feet deep. Based on the operational history, as narrated through interviews with past and present personnel, the levels of contamination detected and the behavior of these chemicals in the environment, the report concluded that groundwater contamination from this site is not likely (ABB, 1992).

As a follow-up to the 1992 study, four groundwater monitoring wells were installed at CS-19 to assess the effect of the site on groundwater. Analysis of samples from these wells indicated the presence of RDX (Cyclonite, an explosive compound) in two of the wells screened at about 110

to 120 feet below surface, suggesting that explosive chemicals had reached the groundwater table. The detection of RDX in the groundwater at CS-19 is suspected to be from past disposal practices(USACHPPM, 1994). The presence of RDX in groundwater also has precipitated a supplemental investigation by the IRP at CS-19.

The U.S. Army Engineers Waterways Experiment Station in Vicksburg, Mississippi has investigated the vertical migration potential of heavy metals at small arms ranges at MMR (Bricka, 1996-Draft Report). Soil samples were collected from borings varying in depth from surface to 90 feet, and analyzed using EPA methods SW-846. The potential for vertical migration was estimated using the one-dimensional advection-dispersion equation for non reactive, dissolved constituents. The predicted downward migration of metals in soils from historical small arms use occurs at an average rate of approximately 2 to 3 inches per year. Within the top 21 inches of soil, the predicted rate is 0.6 inches per year. This figure is conservative, considering the low clay and organic matter content of the soils at MMR. Furthermore, the advection-dispersion equation assumes saturated, homogeneous and isotropic materials under uniform flow. Based on the results of this investigation, it seems that the conditions for vertical migration at the site are considerably more favorable than those at locations with more silty/clayey geological environments. These results are preliminary and approximate. Data gathered during this investigation will be used to refine the estimates of metal migration characteristics during the risk assessment.

2.4 Site Conceptual Model

This section will present a conceptual model of the Impact Area and its environs. The conceptual model is a qualitative description of the site hydrogeology as well as the fate and transport of munitions-related materials. In the Action Plan, the site conceptual model helps to define the appropriate investigation activities by outlining the environmental processes that affect the distribution, movement, and persistence of munitions-related materials. The current conceptual model is based on data on the regional hydrogeology, historic practice at the site, and

observations of the behavior of munitions-related materials at other locations. This information is summarized in the proceeding subsections. As site-specific data become available, the site conceptual model will be refined. It is anticipated that groundwater modeling will be used to supplement the conceptual model. The Completion of Work Report will contain an updated version of the site conceptual model.

2.4.1 Site Hydrogeology

This subsection will present a brief discussion of the hydrogeology of the Impact Area and the surrounding region. This will include a discussion of the lithology, the observed water table, and inferred groundwater flow directions. Much of this material is derived from reports based on joint studies between the US Geological Survey and the National Guard Bureau.

The hydrogeology of western Cape Cod is strongly affected by the glacially-deposited aquifer materials (Masterson et al., 1997). The surficial sediments of the Impact Area and the surrounding region are comprised of four distinct units:

- The Mashpee Pitted Plain. This deposit consists of relatively coarse grained materials and extends from a point approximately 2 miles from the Cape Cod Canal south and east to Nantucket Sound. The unit was formed as a delta. The surficial sediments consist of sands and gravels. The deeper deposits are generally finer consisting of medium to fine sand with small amounts of silt. The lowest unit is glaciolacustrine (glacial lake sediments) in origin and consists of layered fine sand and silt. The estimated hydraulic conductivity of these units generally decline with the increased fine fraction and with depth. The ratio of horizontal to vertical conductivity (anisotropy) changes with the increase in finer material. Thus, the surficial sediments are estimated to have a horizontal hydraulic conductivity of 350 ft/day and the ratio of horizontal to vertical conductivity is estimated to be 3:1 (Masterson et al., 1997). For the deeper

sediments, Masterson et al. (1997) estimated a horizontal conductivity of 30 ft/day and an anisotropy of 100:1.

- The Buzzards Bay Moraine. This unit is located near the western margin of Cape Cod and runs approximately parallel to the western coast. The Buzzards Bay Moraine is approximately one to two miles wide (east to west) and has very complex lithologic characteristics. The moraine has been observed to have numerous discontinuous lenses of fine-grained materials. While the hydrogeologic characteristics of the moraine deposits are believed to be less suitable for water supply (i.e., estimated hydraulic conductivity of 10 to 150 ft/day and wide variation in hydraulic characteristics - Masterson et al., 1997), the hydrogeology of the moraine is generally less well understood than that of the Mashpee Pitted Plain.
- The Sandwich Moraine. The Sandwich Moraine is very similar to the Buzzards Bay Moraine in hydrogeologic characteristics. Masterson et al. (1997) describe the two units together and apparently find few distinguishing characteristics. The Sandwich Moraine Runs approximately parallel to Cape Cod Bay and is approximately one to two miles in width (north to south).
- The Buzzards Bay Outwash Deposits. These surficial deposits lie to the west of the Buzzards Bay Moraine and are apparently similar in nature to the deltaic deposits of the Mashpee Pitted Plain (i.e., a productive unit that is increasingly fine grained with depth).

Masterson et al. (1997) believes that all of these surficial units are underlain by lake-bottom beds of silt and clay. This unit is generally believed to be directly above the bedrock with an approximate thickness of 10 to 80 feet. The hydraulic conductivity of this unit is estimated to be 10 ft/day and the ratio of horizontal to vertical conductivity is estimated to be 100:1.

While the precise boundaries to each of the hydrogeological units are uncertain and there may be some degree of overlap with depth, the Impact Area apparently lies largely on the Mashpee Pitted Plain surficial unit (see Figure 2-4). The two moraines lie at the western and northern edge of the Impact Area. Thus, activities ancillary to the Impact Area (e.g., some gun positions) lie on moraine deposits. Given the water table configuration depicted by Masterson et al. (1996 and 1997), groundwater flow from the Impact Area is likely to include flow through the moraine deposits.

The aquifer present in western Cape Cod is generally an unconfined one. The water table surface (see Figure 2-5 and Masterson et al., 1997) exhibits a high point (elevation of approximately 65 feet above sea level) that incorporates the southeast portion of the Impact Area and extends to the south and east. The water table slopes away from the high point in all directions at approximately equal gradients. Based on this water table, groundwater flow from the majority of the Impact Area will likely be to the north and west. At the eastern and southern portions of the study area, groundwater flow is to the east and south (FS-12 site).

It should be noted that while the general direction of groundwater flow can be hypothesized based on the groundwater contours, the precise path a potential plume would follow is more difficult to estimate. In particular, as pointed out by Masterson et al. (1996), plumes observed in other portions of the MMR are relatively narrow and are deflected horizontally and vertically by changes in the hydraulic conductivity of the aquifer materials.

Groundwater production wells are being developed around the edges of the Impact Area at a distance of approximately two to three miles. These wells are not currently in production. As they are brought into production, they have the potential to affect the groundwater flow patterns beneath the Impact Area.

The unsaturated zone beneath the Impact Area is very extensive. Masterson et al. (1997) presents cross-sections that indicate an unsaturated thickness ranging from 100 feet to in excess

of 200 feet in the vicinity of the Impact Area. Borings completed at CS-19 indicated a water table at approximately 115 feet below ground surface.

Given the nature of the surficial materials at the Impact Area, infiltration through the unsaturated zone is expected to be relatively rapid. As noted in Section 2.2, the rate of aquifer recharge has been estimated at 21 inches per year. A downward vertical gradient is expected in the Impact Area groundwater.

2.4.2 Fate and Transport of Munitions-Related Materials

When considering the fate and transport of chemicals in the environment, it is important to consider the nature of the environment (as described above) as well as the physical-chemical properties of the chemicals and their means of introduction into the environment. Impact on ground water from munitions will be dependent on the physical and chemical characteristics of these compounds and their mobility in the subsurface environment. There are two classes of compounds that may reasonably be anticipated from munitions. The first is explosive compounds. There is a growing body of literature that addresses the environmental fate and transport of explosives (McCormick, Cornell and Kaplan, 1981; Kaplan, 1982; Leggett, 1985; Pennington and Patrick, 1990; Ainsworth et al, 1993; McGarth, 1996; Townsend and Meyers, 1996, Brannon and Myers, 1997). Explosives are subject to degradation and sorption in the subsurface environment. The second class of compounds are metals. Metals do not degrade since they are elements, but they are subject to chemical reactions and sorption.

2.4.2.1 Explosive Compounds

The literature on the environmental fate and mobility of explosive compounds focuses on TNT, RDX, and HMX. These were widely used high energy explosives and have been found in the environment at other sites.

2.4.2.1.1 TNT

2,4,6-trinitrotoluene (TNT) is a crystalline solid at room temperature. It is slightly soluble in water with a solubility of 130 mg/l (Urbanski, 1964 cited in McGrath, 1996).

TNT degrades both abiotically and as a microbiologically mediated reaction (Townsend and Meyers, 1996). Microbiogically mediated degradation is typically faster than abiotic and the reaction proceeds fastest under anaerobic (oxygen free) conditions (Townsend and Meyers, 1996). The principal degradation products are 2-amino-4,6-dinitrotoluene (2A-DNT), 4-amino-2,4-dinitrotoluene (4A-DNT) and 2,6-diamino-4-dinitrotoluene (2,6-DANT). There is evidence that these degradation products are also toxic (Honeycutt et al, 1996). Complete mineralization of TNT has been documented through cometabolism (TNT was not the only source of carbon for the microorganisms) under aerobic conditions (Gunnison et al, 1993).

Volatilization is not an important environmental process for TNT. TNT exposed to sunlight degrades via photolysis (McGrath, 1996).

Sorption is an important process affecting the mobility of TNT. Partition coefficients have been derived for a variety of surface soils although many of these studies failed to account for transformations of TNT during the experiments (Townsend and Meyers, 1996). Partition coefficients (sorption) are higher for clay and silt than sand. Although some investigators have found a correlation between organic carbon content and TNT sorption, the primary sorption mechanism is sorption on inorganic surfaces (Pennington and Patrick, 1990).

2.4.2.1.2 RDX and HMX

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX or cyclonite) is a crystalline solid at room temperature. It is slightly soluble in water with a solubility of 42 mg/l (Sikka et al, 1980 cited in McGrath, 1996). Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetraazocine (HMX) is a crystalline solid at room temperature. It is virtually insoluble; its solubility is 2.6 mg/l (Spanggord, 1982 cited in McGrath, 1996).

RDX and HMX degradation takes place only under anaerobic conditions. Although several investigators have noticed degradation of RDX and HMX under aerobic conditions, it only occurs in clay and silt soils where there may be microanaerobic zones where anaerobic degradation occurs. It is suspected that RDX and HMX degradation are microbiologically mediated processes. The degradation products of RDX and HMX are not known because of the lack of analytical protocols for these compounds (Townsend and Meyers, 1996).

Volatilization is not an important environmental process for RDX and HMX. RDX and HMX exposed to sunlight degrade via photolysis (McGrath, 1996).

Sorption is an important process affecting the mobility of RDX and HMX. Partition coefficients have been derived for a variety of surface soils (Townsend and Meyers, 1996). RDX is slightly less sorptive than HMX which in turn is less sorptive than TNT. The impact of organic carbon content on sorption is unknown, although partition coefficients (sorption) are higher for clay and silt than sand indicating that sorption to inorganic surfaces dominates.

2.4.2.1.3 Other Explosive Compounds

Other explosive compounds include N,2,4,6-tetranitro-N-methylaniline (tetryl), pentaerythritol tetranitrate (PETN), and ammonium picrate. Information on the environmental fate and effects of these compounds is limited. Their use in munitions was limited compared to TNT, RDX, and HMX. Environmental testing includes compounds such as 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitroluene (2,6-DNT) and 1,3,5-trinitrobenzene (TNB). These compounds are not used as explosives; they are byproducts of TNT manufacture and are typically found with TNT. They have been found at sites where contamination of the environment with TNT occurred.

2.4.2.2 Metals

The metals related to munitions are antimony (Sb), arsenic (As), barium (Ba), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), and zinc (Zn). Antimony, As, Ba, Cu, Pb, Hg, and Zn are known

as heavy metals. They normally only occur in trace amounts in uncontaminated aquifers. They have somewhat similar fate and transport properties. Their occurrence in ground water will be controlled by the oxidation state of ground water (generally the oxygen content), solubility and sorption onto inorganic surfaces. In the absence of reducing (no oxygen) conditions, these heavy metals are immobile in ground water. They exist in the subsurface adsorbed to iron and manganese hydroxides (Jacobs, 1997). Uncontaminated ground water at MMR is oxidizing, slightly acidic, and low in total dissolved solids, so heavy metals would be immobile. The recent investigation of inorganics in MMR ground water found that there were no sites with heavy metal contamination of ground water. All of the plumes that had elevated heavy metal concentrations could be explained by reducing conditions in the aquifer that allowed heavy metals to go into solution, or ground water samples had entrained suspended solids with sorbed heavy metals. (Jacobs, 1997).

The remaining metal related to munitions is Fe. Iron is ubiquitous in the Sagamore lens aquifer. Under normal aquifer geochemical conditions, aerobic and slightly acidic dissolved iron concentrations are extremely low (< 100 micrograms/liter) (Jacobs, 1997). The subsurface iron exists as ferric hydroxide, which is insoluble. In the absence of organics in ground water causing reducing conditions, Fe will be immobile in the subsurface.

2.4.2.3 Distribution of Munition-related materials to the Environment

Materials derived from munitions were deposited through two broad classes of activities: practice firing into the Impact Area and activities associated with disposal of munitions, propellants, etc. Practice firing is likely to result in projectile materials being introduced into a relatively broad area (e.g., several hundred feet around a target) but the materials (e.g., munitions fragments and/or unexploded ordnance) are likely to be distributed in a very heterogeneous fashion within that area (Jenkins et al., 1996). Projectile materials are not expected to be found at great depth. Unexploded explosive materials tend to retain their crystalline structure in the environment and

to leach dissolved organics at a low rate (Jenkins, 1997). Metal fragments would be expected to behave in a similar fashion. Therefore, a reasonable description of the projectile remnants is that each fragment acts as a localized, relatively low-grade source of its component materials. Evaluation of the potential impact to groundwater quality should consider the integration of these individual sources over the area(s) affected.

Practice firing may also result in the introduction of propellant materials into soils in the vicinity of the gun position. Such materials are likely to result from deposition of particles in air suspension and, therefore, are likely to be found relatively uniformly distributed in surface soils around the gun positions.

Materials disposal is likely to have taken three different forms: simple disposal onto the soil surface, burning of materials (e.g., propellant bags), and "wash-out" of propellant using water followed by disposal of the water on the ground. The first two of these activities is likely to result in relatively localized, uniform distribution of materials in soils. Wash-out activities have the potential to introduce materials in suspension and/or in solution deep into the unsaturated zone due to the rapid movement of the wash water through the soils.

2.4.2.4 Fate and Transport Summary

The following conclusions are based on the literature review of the fate and transport of munition-related materials in the environment and consideration of the MMR site conditions.

- The persistence and mobility of explosive materials is relatively complex and is likely to vary substantially with site conditions. For compounds such as TNT, transformation is likely to be an important process. Sorption to soil and aquifer solids is also likely to be important but is not necessarily correlated with soil organic carbon content (Jenkins, 1997). RDX is generally less sorptive and apparently undergoes more complete mineralization than does TNT.

- While both TNT and RDX are relatively poorly water soluble, both compounds are polar. Their poor water solubility derives from their high stability in crystal form rather than non-polar interactions with water. This helps to explain why these explosives are relatively stable in soils yet can have relatively high mobility in groundwater once they are in solution (Jenkins, 1997).
- Metals are affected by reactions with solid surfaces and other ions in water solution (i.e., sorption and precipitation, respectively). While metals are persistent, they may have very high affinity for solids and therefore move very slowly in groundwater. Increased mobility of metals is generally associated with low oxidation-reduction potentials which, in turn, is often associated with high concentrations of degradable organic compounds.

2.4.3 Summary of the Conceptual Model

The following conceptual model will be organized along the potential migration pathway of munitions-derived materials. The elements of the potential migration pathway are: (1) deposited materials subject to leaching in surface and shallow subsurface soils; (2) migration of materials through the unsaturated zone with infiltrating precipitation; and (3) migration of materials in groundwater. Each of these potential steps will be defined to the extent possible based on the available data. If major uncertainties exist around a process, this will be highlighted.

The munitions-related materials in and around the Impact Area are most likely to be found in surface soils. This is consistent with the majority of site activities as well as previous characterizations of the site. The possible exception to this is where wash-out activities may have resulted in rapid infiltration of materials into the unsaturated zone. Generally, fragmented munitions (both organics and metals) are best considered to be very localized, low grade sources that accumulate over some area. Major outstanding questions to be resolved in this investigation are the density of the fragments as well as the extent of the affected area. In certain locations

such as around gun positions, soils may be more uniformly affected by propellant materials. Outstanding questions in these locations is the concentration of materials in the soil as well as the lateral extent of the materials.

Given the high rate of infiltration likely to occur in the Impact Area and its environs, careful evaluation of the vertical transport of munitions-related material should be made. Two factors have the potential to limit the vertical migration to the water table: the relatively poor leachability of munitions materials from fragments and potential from reaction in, and sorption to, the unsaturated zone solids. The latter potential is especially important given the depth of the unsaturated zone at the Impact Area. While the original munitions fragments are likely to leach poorly regardless of conditions likely to be encountered, it is difficult to estimate the mobility of the materials once they enter water solution. The rate of sorption and degradation for munitions-related materials has been shown to vary substantially with site-specific conditions. Therefore, the vertical extent of munitions-related materials observed at the site will be important in refining the conceptual model. It will be important to consider the soil conditions and the means of introduction when evaluating migration through the unsaturated zone.

As materials leave the bottom of the unsaturated zone, they will enter the groundwater. Migration in groundwater will occur according to the distribution of hydraulic head and hydraulic conductivity within the aquifer. From the Impact Area, groundwater will ultimately flow toward one of the coasts. Interaction with downgradient fresh surface waters is possible. In the near field, there is a possibility that flow will have a downward component. As described by Masterson et al. (1996), the groundwater flow paths are affected by changes in lithology within the aquifer. For this reason, it is difficult to predict the exact path of any potential groundwater plume. Groundwater transport velocities are generally believed to be relatively fast due to the high hydraulic conductivities of the various units. Flow to the north and west (the predominant

flow direction from the Impact Area) is likely to be slower than to the east and south as the hydraulic conductivity in the moraines is lower than in the Mashpee Pitted Plain but the head gradients are similar. Within groundwater, munitions-related materials will be subject to sorption, degradation, and dispersion. The effectiveness of these processes at attenuating down gradient concentrations is not clear at this point in time.

3.0 TASK EVALUATION AND SCOPE

This study is being conducted to determine the effects of military operations on the groundwater beneath the training ranges and Impact Area. The tasks are scoped to provide data on groundwater quality, verify the groundwater flow pattern in the study area, and provide for the preliminary evaluation of suspected source areas. This information will be used in the preliminary risk and groundwater quality evaluations. As more understanding of the hydrogeology of the area is gained, the scope of the study will be revised as needed. NGB will develop a Response Matrix to describe the decision tree for responding to issues resulting from the findings of the field investigations. In accordance with the Response Matrix, additional investigation wells and/or soil samples will be used to collect data needed to characterize the level and extent of any contamination that may exist; and collect geotechnical and hydrogeological data to formulate policies for the long range protection of groundwater beneath the training ranges and Impact Area.

The initial scope of work for the training ranges and Impact Area study will include the installation of 42 permanent and seven semi-permanent ground water investigation wells; collection and chemical analysis of soil, surface water, storm water, sediments and groundwater samples; and the search for and review of records relating to the use of the site, fate and transport of suspected contaminants, and the general groundwater quality of the MMR. The investigation wells, supplemented by the LRWSPAT water source investigation test wells and selected IRP monitoring wells at the IRP sites around the study area, will provide control points for groundwater evaluation data that will be used to verify the groundwater flow model. Soil, surface water, storm water, and sediment samples will provide data for the preliminary evaluation of suspected sources; and groundwater samples will provide data for the evaluation of the quality of groundwater beneath the study area. Additional investigation of suspected sources may be considered if the initial data warrants it, and all additional investigation wells and/or soil

sampling locations will be determined in consultation with the EPA, according to the decision criteria contained in the Response Matrix to be prepared for this study.

Figure 3-1 shows the proposed investigation well locations. The locations of these wells were selected based on the current understanding of groundwater flow and anticipation of downgradient locations from the suspected source areas. The nested well locations are intended to investigate probable vertical gradients that may control fate and transport of contaminants. The wells located in the Impact Zone (Site 1, burning area, and Site 3) will be semi-permanent, and the closure criteria will be agreed to with the EPA. These wells will be protected against accidental impact. and will exist long enough to characterize the aquifer.

The scope of the investigation will include the installation of investigation wells in and around the training range and Impact Area, the collection and analysis of environmental media, aquifer characterizations and the completion of a risk assessment. The new wells will be supplemented by selected IRP monitoring wells. This investigation well network will also include the potable water source investigation test wells installed by Stone and Webster earlier this year under contract to the Air Force Center for Environmental Excellence (AFCEE). The new and existing wells will be used to assess groundwater flow and quality beneath the training ranges and Impact Area.

Figure 3-2 shows locations for soil, surface water and sediments sampling. The scope of this sampling is designed to provide for a preliminary evaluation of potential sources and probable migratory routes of contamination. Surface soil samples will be collected at 40 sites within the training range and Impact Area, including twenty-three gun and mortar positions; the two demolition areas; the five potential source areas, seven burn areas, and one ground scar area identified by the ERI report; and two drainage swales. Subsurface soil samples may also be collected at these 40 locations, depending on the results of the surface soil analyses. Subsurface soil samples will be collected at 10-foot intervals from six borings and at the top and bottom of the unsaturated zone for seven borings in the Impact Zone. Surface water and sediment samples

will be collected from five ponds and a swamp. The sampling at suspected sources will be done on a grid system. The grids will be based on a review of aerial photographs and field observations to identify the most heavily used areas (focal zone) of the suspected areas for soil sampling. Sampling locations in ponds and drainage swales will be based on topography, visual field observations and historical use of the areas contributing flow to the drainage. Groundwater quality data will be collected from all the new wells, approximately 18 IRP wells, and the LRWSPAT test wells. Additional investigation at these sites will be based on the results of the archives search, analytical results, and other information.

The primary compounds of interest are those derived from munitions and their degradation byproducts. Therefore, the focus of the analytical program will be to identify compounds relating to explosives. Furthermore, the sampling and analytical programs will be designed to attempt to distinguish compounds derived from explosives, and those resulting from other activities not related to typical range activities. However, for completeness, and in order to comply with the MMR IRP Quality Assurance/Quality Control (QA/QC) guidelines for analytical programs for environmental investigations at MMR, the list of analytes will include Target Analyte List Inorganics (TAL inorganics), Target Compound List Volatile Organic Compounds (TCL VOCs), Target Compound List Semi-Volatile Organic Compounds (TCL SVOCs), TCL for Pesticides/PCBs, Herbicides, Ethylene Dibromide (EDB) and Methyl-Tert-Butyl-Ether (MTBE).

3.1 Investigation

The history of the numerous ranges, their use and types of munitions used over the years is uncertain. However, some previous investigations (USAEHA, 1987; USACHPMM, 1994) at typical ranges, artillery and mortar locations, and the CS-19 site (see Figure 3-1) located within the training range and Impact Area have provided insight on activities occurring in the study area.

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DRAWN	AJH 2/97
CHECKED	MLL 2/97
APPROVED	DHK 2/97

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Ⓑ Shooting Range Locations
○ Gun Position
△ Mortar Position

Source: Defense Mapping Agency, 1988

MMR IMPACT AREA WORKPLAN
Figure 2-7
Other Sources in the Study Area

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0 1000 2500 5000
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Source: Analysas, 1995 and US Defense Mapping Topo Maps

MMR IMPACT AREA WORKPLAN

FIGURE 3-1
PROPOSED MONITORING WELLS
LOCATION MAP

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MMR IMPACT AREA WORKPLAN

FIGURE 3-2
SOIL, SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

SCALE: | CONTRACT NO.: 97301.10 | DATE: 5/97

3.1.1 Archives Search

The historical use of the Impact Area over the last 10 years has been well c previous 50 years was not. Identification and verification of the type munitions used at MMR will include searching the Munitions Items Disp (MIDAS) database, primary supply depot records, databases from other mili the same periods, and interviews with former and current employees of th following information will be collected:

- The type of munitions used at the installation
- Time periods each munition was used, and the quantities per time
- Physical and chemical components of each munition, including fu
- Types and locations of the target for each munition
- UXO density based on percent duds and quantity used per area
- UXO depth based on historical range reports, the applications of Engineers, Huntsville research models, and UXO surveys associat groundwater sampling

In addition to munitions used, the archives search will include a review incidences of improper and/or accidental disposal of waste in the Impact Ar previous investigation at this and other installations with similar historic reviews will be compared to data from aerial photographs and interview with

similar environmental conditions will be collected and summarized. This report will summarize the references, rather than duplicate, the methodologies and findings of the previous investigations.

This task will be initiated with a meeting between NGB and EPA at MMR to discuss research methods and public involvement. Interim reports of the records search will be provided in project review meetings with NGB and EPA that will summarize information collected and schedule for work. Final results of the archives search will be documented in three reports, including

- The unexploded ordnance report will provide detailed information on the munitions used at the Impact Area;
- The historical range use report will provide detailed information on the prior use of the Impact Area and the potential for environmental impacts from these uses; and
- A summary of environmental fate and transport will present available information on site hydrogeology, a review of investigations at sites with similar environmental conditions, and the fate and transport of munitions-related chemicals.

Each document will include a description of the research methods, results and their interpretations, recommendations for additional work as necessary, and supporting information including maps, photographs, and drawings.

3.1.2 Review of Aerial Photographs

The data requirements of this project will include the review of new and historical aerial photographs. Aerial photographs will be analyzed to identify historically heavily used areas for soil sampling. These heavily used areas are the most probable sites where soil contamination may have occurred. An aerial photographic analysis of the Impact Area identified six probable sites, which included CS-19, and numerous other locations of interest for environmental investigation (ERI, 1994).

3.1.3 Unexploded Ordnance Survey

All access roads, investigation well and soil sampling locations will be surveyed and cleared for unexploded ordnance (UXO) before the investigation. The depth of UXO screening during boring for investigation well location will be determined by the result of modeling currently being conducted at Huntsville District Corps of Engineers, and the professional judgment of the UXO clearing contractor. Similarly, in the event of subsurface sampling within the Impact Area, the depth to which the UXO screening will go may depend on the result of the Huntsville modeling.

3.1.4 Surface Water, Soil and Sediments Sampling

Figure 3-2 is a map showing proposed locations for surface water, surface soil and sediments sampling. Natural depressions and swales will be investigated as probable conduits and areas of compound accumulation resulting from storm water run-off. Subsurface soil samples will also be collected during borehole completion for both permanent and temporary investigation well installation. The locations for these investigation wells are shown on Figure 3-1.

3.1.4.1 Surface Water and Sediments Sampling

Surface water and sediment samples will be collected from four ponds in the training range and Impact Area, one pond at the Rod and Gun Club, and one swamp location just north of the Impact Area. Most kettle holes in the study area are dry, and only collect water during and immediately after large rainstorms before it all infiltrates and/or evaporates (see Section 3.1.4.4 Storm water Sampling). However, the swamp area and five of these kettle holes appear to be deep enough to possibly intersect groundwater, and these will be sampled.

3.1.4.2 Soil Sampling

The soil sampling program will consist of a two tier program including:

(i) surface soil sampling, and

(ii) subsurface soil sampling and lithologic logging at investigation well locations.

Surface soil sampling will be conducted at the two demolition areas; five potential source areas (CS-19, also known as site #2, is being investigated by IRP), seven burn areas, and one ground scar area as depicted by the ERI report; drainage swales and surface depressions; and 23 gun and mortar positions. The objectives of this sampling are to evaluate the maximum concentration and spatial variability and distribution of contaminants at each location. Due to the spatial heterogeneity of munitions compounds in the environment, soil sampling will be conducted using sampling grids and samples compositing as described in section 4.1.4 of this work plan. Also, three mortar positions and two gun positions will undergo additional soil sampling as representatives of all gun and mortar positions.

During investigation well installation, subsurface soils will be sampled at 10 foot intervals. The samples will be used for lithologic logging and field screening using a Flame Ionization Detector (FID). A determination will be made in the field based on FID readings whether any of the samples will be submitted for laboratory analysis.

Subsurface sampling locations at areas where contamination may be expected to occur at depth will be determined through surface sampling analysis, site characterization, archival information, interview results and consultation with the EPA. At well locations within the Impact Zone, subsurface soil samples will be collected every ten feet of depth. At seven locations in the Buffer Area, subsurface soil samples will be collected at the top and bottom of the unsaturated zone. The analytes list for these samples will include explosive compounds and metals. In addition, the 10-foot deep sample from each of these locations, and any sample with an FID detection above background, will be analyzed for all target compounds.

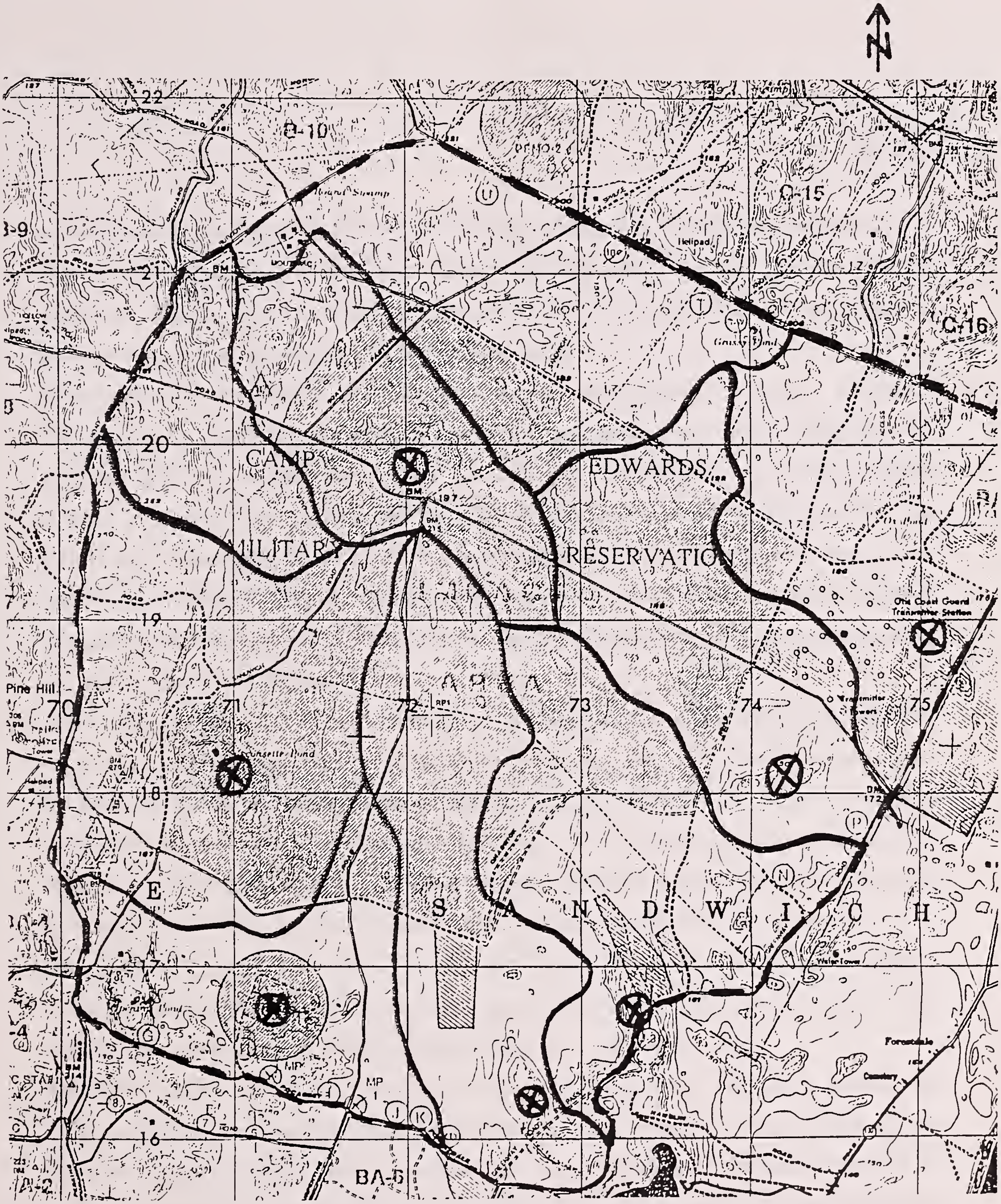
3.1.4.3 Groundwater Sampling

Upon completion of investigation well installation, and after allowing enough time for stabilization, groundwater samples will be collected for analysis. Groundwater data will be collected from all newly installed wells, the nine LRWSPAT test wells (one of the ten is dry), and 18 IRP monitoring wells including eight from CS-19, six from FS-12, two from CS-18, and two from CS-1 (see Figure 2-6). Before sampling, the depth to groundwater in each well will be measured and recorded. That information will be augmented by water level measurement from USGS, IRP, and LRWSPAT monitoring wells in and around the study area. Groundwater sampling will be conducted using the July, 1996 EPA low stress (low flow)purge and sampling procedure.

3.1.4.4 Storm Water Sampling

Because of the sandy soils and lack of impervious surface within the Impact Area, there is very little storm water runoff as described in Section 2.2.1. Precipitation infiltrates into the sandy soils and becomes ground water recharge. Only the largest storm events will generate storm water runoff. Most kettle holes in the study area are dry, and only collect water during and immediately after large rainstorms before it all infiltrates and/or evaporates. Sediment samples will be collected from areas where storm water flows off the Impact Area and from dry kettle holes within the Impact Area.

Based on the topographic map, nine (9) subwatershed areas within the Impact Area were determined. Storm water will be sampled at each subwatershed downgradient area to which the surface runoff will converge. In order to better define the water quality of surface runoff from Impact Area, seven (7) sampling stations were located (Figure 3-3). Drainage area of each



Drainage Areas

Automatic Sampler Locations

DESIGNED ____ DATE DRAWN ____ DATE CHECKED ____ DATE APPROVED ____ DATE	ENGINEERING TECHNOLOGIES ASSOCIATES, INC. ENGINEERS • PLANNERS • SURVEYORS 3458 ELLICOTT CENTER DRIVE SUITE 101 ELLICOTT CITY, MARYLAND 21043 BALTO. 461-9920 WASH. 621-4460	Figure 3-3 Storm Water Sampling Locations SCALE: CONTRACT NO.: DATE: SHEET:

subwatershed was estimated. As shown on the Figure 1, the majority of the surface runoff at some sampling locations will be from the Impact Area with some runoff from the outside of the study area. Among the nine subwatershed areas, two will not be sampled because the majority of the runoff flows onto the Impact Area from adjacent land.

Storm water will be sampled from those seven stations using automatic samplers. Automatic samplers can be programmed in advance based on an anticipated storm event to collected flow weighted composite samples through wet weather periods. The sampler would collect a sample at equal intervals of flow past the stations. Specific sampling intervals will depend upon the storm event. One should notice that, however, predicting the storm water discharge through the station is extremely difficulty or even impossible, especially in MMR, where the surface runoff is virtually nonexistent except for extreme events, due to the highly permeable nature of the sands and gravels underlying the area.

Storm water sampling will be conducted during a six month period during which a maximum of six storms will be sampled, once per month. The climate data from EPA (1992) indicate that in the northeast coastal rain zone, the annual average number of storms is 63. With one standard deviation of 8, the number of storms ranges from 55 to 71. For the six-month period, the number of storms is expected to be 27 to 35. The average storm volume is 0.66 inches with a standard deviation of 0.68. Thus the storm with one standard deviation above average will have the volume of 1.36 inches. Automatic samplers will be programmed to collect flow weighted composite samples over the predicted hydrographs calculated from the 1.36 inch storm. The average storm duration in the northeast coastal zone is 11.7 hours (EPA, 1992).

Automatic samplers will be programmed to fill the bottle, if possible, for the storm. Due to the highly permeable sands and gravels underlying the area, the average storm (0.66 inches) is not expected to generate enough surface runoff for the discharge at sampling stations. If no storm of 1.36 inches occurs, the sampler will be programmed to collect the samples for smaller storms. Specific sampling intervals will depend on the storm runoff and duration. After the storm,

bottles will be collected and sent for lab analysis. The water samples will be analyzed for suspended solids, total phosphorus, nitrate/nitrite, ammonia, explosives, total heavy metals, and dissolved heavy metals

3.1.5 Investigation Well Installation

The scope of the investigation well installation will initially include 42 permanent and seven semi-permanent wells. The number and locations of wells will be subject to change and revision in the field as data gathered is reviewed, and as we gain a better understanding of the hydrogeology of the site. All changes will be made in consultation with the EPA.

The monitor well installation program will be required to provide groundwater data collection points, and hydrologic control points to:

(i) Assess the quality of groundwater beneath the study area; and

(ii) Provide a good understanding of groundwater levels and movement -- both horizontal and vertical-- to help understand the flow of groundwater.

Initially, 25 locations have been selected to install 42 permanent wells (See Figure 3-1). At eleven of these locations, a nest of three wells will be installed, including one screened at the water table, one screened above bedrock or the silty clay layer (if present), and one screened at an intermediate depth. The depth of the intermediate well will be determined by the results of laboratory analysis of groundwater samples collected during borehole drilling for installing the deep well. At two of these locations, a nest of two wells will be installed, including one screened at the water table and one screened in above the bedrock or the silty clay layer (if present). All 13 of the deep well locations will be drilled to bedrock. The recommended sites for drilling to bedrock are shown on Figure 3-1, and may be revised in consultation with the USGS and EPA.

At each nested well location, a boring will be drilled, and soil samples collected at 10 foot intervals in the unsaturated zone for lithology and head space screening. At deep borings below the water table, groundwater samples will be collected every 10 feet for screening and analysis to determine

the water quality. Results of these analyses will be used to determine well depth and screen intervals for the intermediate depth well. If no contamination is present based on the screening analysis, a review of the lithology and hydrogeology will determine the screen interval. The depths of the remaining 12 wells will be determined after completion of the 37 nested wells and an evaluation of the data. When no contamination is found based on the screening analysis at the nested well sites, depth of the 12 individual wells will be set at the water table. This depth may change after review of the nested well lithology in consultation with the USGS and EPA.

Investigation wells will be drilled and installed by a driller under the supervision of a qualified geologist or hydrogeologist who will log the boring, collect and prepare samples, and document well completion. For purposes of this project, the hydrogeologist/field supervisor for the drilling program will be required to keep a detailed record of the daily activities. This record will include but is not limited to drilling conditions, problems encountered and the methods employed to resolve them, weather conditions, and any condition and/or activity bearing effects on data quality and procedures.

After the desired depth is reached, the investigation wells will be installed using 10 feet of 0.010-inch factory slotted Schedule 80 Polyvinyl chloride (PVC) 2.5-inch diameter well screens and the appropriate length of risers to provide for a 2-foot stick-up above surface. After installation of the well screen and risers, the well will be completed by installing a sand pack around the well screen to a depth of about five feet above the top of the screen. After placement, a minimum two feet bentonite seal will be placed above the sand pack. The well head will be protected by a metal casing with a locking cap over the PVC stick-up. At locations where nested wells are installed, the deepest well will be installed in the same boring with the shallow well.

Upon completion and after a stabilization period of at least seven days, each well will be developed using the surge and pump method as outlined in the MMR-SOP manual. Well development will be considered complete when the temperature, turbidity, conductivity and pH of the water stabilizes within 10 percent for three consecutive readings.

3.1.6 Elevation and Location Survey of Investigation wells

After installation of the wells, a licensed surveyor will locate investigation wells installed during this investigation. The coordinates of the wells will be presented in the Massachusetts State Plane Coordinate System North American Datum of 1927. Vertical surveys of the wells will be based on the National Geodetic Vertical Datum of 1929. Horizontal accuracy of the survey will be within 0.1 feet, and vertical accuracy will be within 0.01 feet. Well stickup from ground surface will be determined for the well and protective casings with the same level of accuracy. A permanent marker will be placed at the points of measurement on each casing.

3.1.7 Well Site Clean-up and Restoration

After completion of field activities at all sampling and investigation well locations, all equipment and materials not associated with the well itself will be promptly removed. The area will be restored to its original condition by removing trash, excess grout and concrete and grading to remove ruts. Seeding, mulching and general landscaping may be required. Investigation Derived Waste (IDW) will be handled in accordance with the modified IRP SOPs as described in section 4.1.8 of this work plan.

3.1.8 Water Level Measurements

Subsequent to the completion of the survey, groundwater levels in the investigation wells will be measured and recorded using an electronic measuring device. The probe of the device is lowered into the well until it hits the water table. A continuous tone is emitted when the probe contacts water. The depth to water is read off the calibrated tape to which the probe is attached. Water levels will be measured with 0.01 foot accuracy; and the data, together with surveying data, will be used to generate a groundwater elevation map which will be updated periodically throughout the investigation to insure optimum well locations.

3.1.9 Aquifer Testing

Aquifer testing will be conducted in an attempt to identify the hydrogeologic conditions and controls on groundwater flow and contaminant transport in the study area. The objective of this testing will be to qualitatively determine aquifer parameters that control flow patterns and to determine the relationship between these flow patterns and the transport of any contamination that might exist. Further still, the results of this effort will be used to refine existing models to predict the regional flow and transport for the whole installation. The activities of this task will include slug and/or pumping tests to estimate hydraulic conductivity and determine the relative permeability and conductivity of the various strata being monitored at the site.

3.2 Preliminary Risk Evaluation

A Preliminary Risk Evaluation (PRE) will be conducted for each exposure area. A PRE is a screening-level risk assessment that supports risk management decision making. The PRE will identify those compounds of concern which are found in concentrations that may have potential adverse effects on humans and ecological receptors.

The PRE will be conducted using the Tier I procedure and guidelines provided in the MMR Risk Assessment Handbook, Volumes I and II, Massachusetts Military Reservation (CDM, September 1994), updated to meet the focus of this study. Preliminary risk evaluation screening procedures (Tier I) are designed to conservatively identify sites that require further investigation. They are designed to be conservative; identifying sites that, in fact, may not present any actual risk. A work plan for performing the PRE will be provided to the EPA before initiation of the risk evaluation.

3.3 Follow-on Actions

The following actions may be required to fulfill the goals of the EPA Region I Administrative Order.

3.3.1 Risk Assessments

The Army National Guard, in consultation with EPA, will complete human health risk and ecological risk assessments. The Army National Guard will partner with other federal agencies who are recognized experts in the risk assessment field. These agencies will work with the supervising contractor to gather information, augment existing data and complete the risk assessments. These risk assessments will include modeling the fate and transport of all contaminants found as a result of this investigation and will be used during the development of any required response plans and the long term monitoring program.

3.3.2 Response Plans

Response plans will be prepared and implemented as conditions warrant. All data evaluation will be conducted in consultation with EPA. At any time sample results indicate additional investigation is required at a particular site, the ARNG will direct the supervising contractor to prepare a response plan. The preparation of the response plan will be coordinated with EPA, MADEP and the IRP. ARNG will brief the citizens advisory committee of the need for and contents of the response plan. The response plan will be initiated immediately after receiving approval of the plan's contents from EPA.

3.3.3 Installation Response Program (IRP) Investigation Referral

Throughout the duration of this investigation, the ARNG will coordinate with the IRP. All data gathered during the investigation will be made available to the IRP. A partnership will be established with IRP to ensure all response plans are coordinated. In the event that a source of contamination is located and determined to be eligible for inclusion in the IRP, the partnership

ensure that the proper investigation is conducted. The proper agency will develop any required response plan and will ensure all necessary actions are taken to comply with that plan.

3.3.4 Long Term Monitoring Program

After the initial data has been gathered and the groundwater model has been verified, ARNG may develop a long term monitoring program. This monitoring program will be developed in consultation with EPA, USGS, MADEP and the LRWSPAT. Additional input may be requested from the IRP and other federal agencies. The long term monitoring plan will be developed using the results of the groundwater modeling, the risk assessments and source evaluations. Additional permanent wells may be installed in support of the long term monitoring program.

4.0 SAMPLING AND ANALYSIS

4.1 Sampling Program

During the field work, environmental samples will be collected from surface soils, subsurface soils, surface water, sediments, storm water, and groundwater for laboratory chemical analysis. All field activities will be conducted according to standard operating procedures outlined in the MMR-IRP "Standard Operating Procedures for Environmental Investigations at MMR" (CDM, 1993) subject to the changes proposed in this work plan. Table 4-1 summarizes the initial sampling program, showing the number and types of samples to be collected, sampling locations and analytical methods.

4.1.1 Field Screening

All soil samples collected during this investigation will be subjected to headspace screening. This will be done by filling half of a 4-oz. glass jar with portions of the sample. The jar will be covered with aluminum foil and a lid, and allowed to equilibrate at room temperature (70^{o} F) for approximately 15 minutes. This will allow any volatile organics in the sample to equilibrate within the air in the headspace above the sample. The probe of a Flame Ionization Detector (FID) will then be inserted through the aluminum foil into the headspace. The reading registered on the FID will be recorded.

4.1.2 Well Installation

Investigation wells will be installed at the locations proposed in Section 3.1.5 of this work plan and at additional locations as needed based on the evaluation of data collected during the study in consultation with the EPA.

Table 4-1
Sample Types, Numbers and Analytes

Media	Location	Interval	Type	#	Analytes
Surface Soil	5 potential source areas	0-6"	grab*	105	Exp1, InO
	5 potential source areas	0-6"	composite	15	Exp1, InO
	5 potential source areas	0-6"	grab	15	all
	2 demo areas	0-6"	grab*	42	Exp1, InO
	2 demo areas	0-6"	composite	6	Exp1, InO
	2 demo areas	0-6"	grab	6	all
	18 gun & mortar positions	0-6"	grab*	126	Exp1, InO
	18 gun & mortar positions	0-6"	composite	18	Exp1, InO
	18 gun & mortar positions	0-6"	grab	18	all
	5 gun & mortar positions	0-6"	grab*	105	Exp1, InO
	5 gun & mortar positions	0-6"	composite	15	Exp1, InO
	5 gun & mortar positions	0-6"	grab	15	all
	7 burn areas + 1 scar	0-6"	grab*	168	Exp1, InO
	7 burn areas + 1 scar	0-6"	composite	24	Exp1, InO
	7 burn areas + 1 scar	0-6"	grab	24	all
	2 drainage swales	0-6"	grab	12	Exp1, InO, all
Total Surface Soil for Exp1 & InO		0-6"	composite	90	Exp1, InO
Total Surface Soil for Exp2 (10% of Exp1)		0-6"	composite	9	Exp2
Total Surface Soil for all analytes		0-6"	grab	90	all
Potential Additional Surface Soil for Exp1 & InO		0-6"	grab*	546	Exp1, InO
Potential Additional Surface Soil for Exp2 (10% of Exp1)		0-6"	grab*	55	Exp2
Subsurface Soil	2 target area borings	every 10'	grab	22	Exp2, InO, all
(unsaturated zone)	2 demo area borings	every 10'	grab	22	Exp2, InO, all
	1 high-use mortar position	every 10'	grab	11	Exp2, InO, all
	1 burn area boring	every 10'	grab	11	Exp2, InO, all
	7 other Impact Area borings	10' + 100'	grab	14	Exp2, InO, all
	5 potential source areas	6-24", 24-48"	grab~	210	Exp1, InO
	2 demo areas	6-24", 24-48"	grab~	84	Exp1, InO
	18 gun & mortar positions	6-24", 24-48"	grab~	252	Exp1, InO
	5 gun & mortar positions	6-24", 24-48"	grab~	210	Exp1, InO
	7 burn areas + 1 scar	6-24", 24-48"	grab~	336	Exp1, InO
Total Subsurface Soil for Exp2, InO, all analytes		10' intervals	grab	80	Exp2, InO, all
Potential Additional Subsurface Soil for all analytes		6-24", 24-48"	grab~	180	all
Potential Additional Subsurface Soil for Exp1 & InO		6-24", 24-48"	grab~	1092	Exp1, InO
Potential Additional Subsurface Soil for Exp2 (10% of Exp1)		6-24", 24-48"	grab~	109	Exp2
Sediment	5 ponds & 1 swamp	0-6"	grab	6	Exp2, InO, all
Surface water	5 ponds & 1 swamp	surface	grab	6	Exp2, InO, all
Ground water	13 new deep wells	deep	grab	13	Exp2, InO
	13 deep borings	every 10'	grab	390	Exp1
	4 new deep wells	deep	grab	4	all
	11 new intermediate wells	Exp screen	grab	11	Exp2, InO
	3 new intermediate wells	Exp screen	grab	3	all
	25 new shallow wells	shallow	grab	25	Exp2, InO
	8 new shallow wells	shallow	grab	8	all
	18 IRP wells	shallow/deep	grab`	18	Exp2, InO, all
	9 LRWSPAT wells	shallow	grab`	9	Exp2, InO, all
Total Ground Water for Exp1		every 10'	grab	390	Exp1
Total Ground Water for Exp2 & InO		see above	grab`	76	Exp2, InO
Total Ground Water for all analytes		see above	grab`	42	all
Storm water	7 subwatershed locations	surface	composite	7	Exp2, InO
Notes:	* discrete samples to be analyzed based on results of composite samples				
	~ discrete samples to be analyzed based on results of 0-6" discrete samples				
	` existing data will be used if analytes and QA/QC are acceptable				
	Exp1 = Explosives by colorimetric methods				
	Exp2 = Explosives by EPA Method 8330				
	InO = Inorganics (including phosphorous, nitrate/nitrite, ammonia)				
	all = all other target analytes (VOC, SVOC, PCB/pest, herb, EDB, MTBE)				

The investigation wells will be drilled and installed by a driller under the supervision of a qualified geologist or hydrogeologist who will log the boring and document well completion. The borings for the wells outside the Impact Area will be drilled using rotasonic drilling technique. Rotosonic drilling is a drilling method that uses high frequency mechanical vibrations to push dual casings and collect continuous core samples of the overburden and most bedrock formations. The system has many advantages over conventional drilling, but the two that are most unique for the conditions at MMR are the abilities to obtain continuous, undisturbed core samples of the sands and to drill through boulders, concrete and debris, thus alleviating the problems that have been encountered by refusal at shallow depths. Due to UXO hazard, locations inside the Impact Zone will be drilled using dual rotary drilling technique. If safety concerns are satisfied, rotosonic drilling may be used within the Impact Area.

When rotosonic drilling is employed, a 4-inch diameter core barrel will be pushed ahead of an 8-inch outer casing using a hydraulic press to collect core samples. The core samples will be used to log the boring. For this initial boring, groundwater samples will be collected every 10 feet and analyzed to characterize the saturated zone of the aquifer. These results will be used to determine the screen interval for the intermediate depth well at the location. After the desired depth is reached, the investigation wells will be installed using 10 feet of 0.010-inch factory slotted Schedule 80 polyvinyl chloride (PVC) well screens and the appropriate length risers to provide for a two-foot stick-up above surface. After installation of the well screen and risers, the outer casing is vibrated back out of the borehole. The vibration positively places well construction materials around the screen and risers.

A similar procedure will be followed when the dual rotary technique is used. Lithologic samples will be collected every ten feet. For the initial well at each cluster location, ground water samples will be collected every ten feet. Well construction will be identical to that proposed above.

All well locations within the Impact Area will be screened for UXO to a depth determined by the application of the Huntsville Army Corps of Engineers model or as determined by the UXO contractor. This UXO clearance will be conducted in two foot increments using a hollow stem auger drill rig. The boring will be advanced in 2-foot increments. Each time the hole is advanced by 2 feet, the drill rig will be moved off the boring to a safe distance so it does not affect results of the test; and also to allow the subcontractor to screen the boring for UXO. This process will be repeated until the boring reaches the desired depth for UXO screening.

Upon completion and after a stabilization period of at least seven days, each well will be developed using the surge and pump method as outlined in the MMR SOP 4-3 (CDM, 1993). Well development will be considered complete when the temperature, turbidity, conductivity and pH of the water stabilizes within 10 percent for three consecutive readings.

4.1.4 Surface Water/Sediment Sampling

Surface water samples will be collected from ponds in and around the Impact Area as described in Section 3.1.4. Surface water samples will be collected using the procedure in MMR SOP 1-1 (CDM, 1993).

Sediment samples will be collected at the same locations as surface water samples are collected. Sediment samples will also be collected from swales and kettleholes where storm water runoff from the Impact Area concentrates as described in Section 3.1.4. Sediment samples at surface water sampling locations will be collected using the procedure in MMR SOP 1-1 (CDM, 1993). Sediment samples in swales, where there is no water, will be collected using the procedures for surface soil sampling (described in Section 3.1.4.2 and MMR SOP 1-3). Samples will be collected on the longitudinal axis of the swale or kettlehole at two locations 50 meters apart. One of the two locations will be at the deepest part of the swale or kettlehole, and the other will be 50 meters uphill. Three samples will be collected at each location: one sample will be collected at the deepest part of the swale or kettlehole (thalweg), and two samples will be collected along an

axis perpendicular to the swale axis on either side of the deep sample at an elevation one foot above the deepest point. Swale or kettlehole sediment samples will be collected to a maximum depth of six inches using the procedures in MMR SOP 1-3 (CDM, 1993).

4.1.4 Soil Sampling

Surface soil sampling will be conducted at gun and mortar positions and at potential source areas within the Impact Zone as described in Section 3.1.4.2.

Every gun position (16 locations) and mortar position (8 positions) will undergo soil sampling with analysis for inorganics, explosives, and other target analytes. The objectives of this investigation are to evaluate maximum concentrations of contaminants at each location, and the spatial variability of these concentrations.

Sampling will be preceded by evaluation of the position for visible evidence of waste materials, discolored soils, or stressed vegetation. Sampling will proceed at this "worst case" location at each position. In the absence of visible contamination the sampling will proceed at a location near the center of the gun or mortar position.

Sampling will be performed using a circular grid that is 4 feet in diameter, with seven borings located at the perimeter and center of the grid. The locations of the sampling grids will be documented by surveying. Each of the seven borings in a grid will be sampled at 0-6 inches using a hand auger.

A portion of each discrete sample will be reserved for headspace analysis using a FID, while the remainder will be homogenized by manually mixing it in a bowl. A portion of each of the seven homogenized samples will be composited into a single sample, with the remainder of each homogenized sample preserved for potential future analysis.

The composite sample from each gun or mortar position will be analyzed for inorganics by CLP ILM04.0, TNT by EPA Method 8515, RDX by the CRREL colorimetric method, phosphorous, nitrate/nitrite, and ammonia. If the composite sample results are above risk screening levels

agreed upon with EPA for inorganics or are detectable for explosives, the discrete samples for the composite will be analyzed using the same methods. Ten percent of all samples analyzed for TNT by EPA Method 8515 and for RDX by the CRREL colorimetric method will be split and analyzed for explosives by EPA Method 8330.

In the event that discrete samples are analyzed, the boring(s) within a grid that have the highest detected concentrations of explosives and metals will be extended for additional sampling from 6-24 inches and from 24-48 inches. Samples from these intervals will be analyzed for explosives and metals using the same methods as the surface soil samples.

The soil sample with the highest headspace screening result will be analyzed for the other target analytes (VOC, SVOC, EDB, MTBE, pesticides/PCB, and herbicides). In the event that there are no headspace detections, this sample will be collected from the grid point having the most evidence of contamination based on physical appearance, or if there is no such evidence then from the center of the grid.

The need for additional sampling at all gun and mortar positions will be evaluated based on the results of these preliminary composite and discrete samples, in accordance with the Response Matrix to be agreed upon with EPA.

Target zones, areas identified as potential source areas, and selected gun and mortar positions will undergo more intensive soil sampling with analysis for inorganics, explosives, and other target analytes. The objectives of these investigations are to determine contaminant levels that are representative of the conditions at these areas, and to evaluate variability of these concentrations. The gun and mortar positions will include areas that are representative of high-, medium-, and low-use conditions based on records maintained by ARNG. (The high-use gun position GP-9 has already been characterized by the IRP as CS-18). The gun and mortar positions and potential source areas will be sampled as described in the preceding paragraphs, except that two additional sampling grids will be used at each location, located along a line at 10 feet and 50 feet from the "worst case" grid position, as indicated for a hypothetical source area in

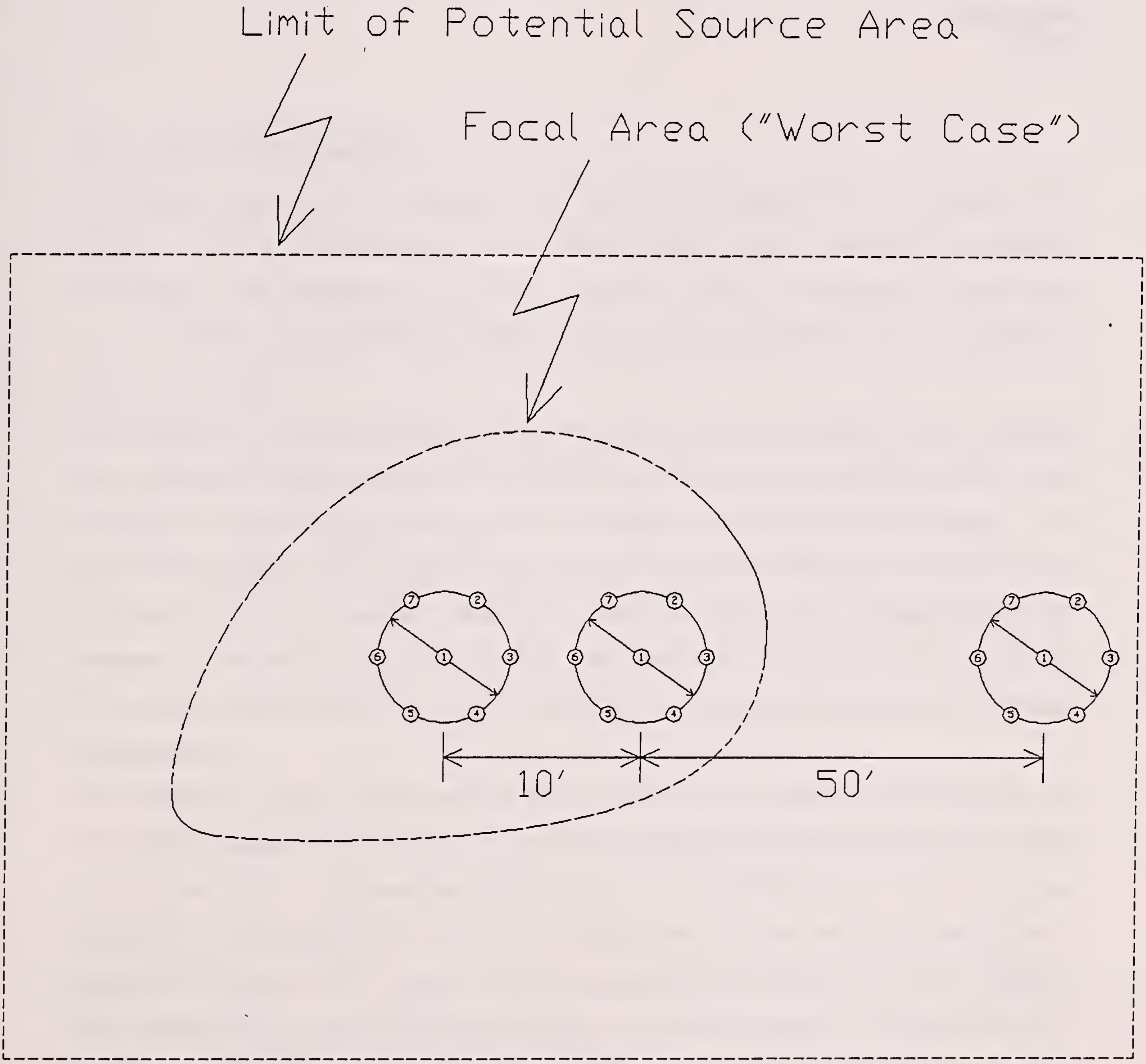
Figure 4-1. The locations of the sampling grids will be documented by surveying. The need for additional sampling at the potential source areas will be determined based on the results of these composite and discrete samples, in accordance with the Response Matrix to be agreed upon with EPA.

At well locations within the Impact Zone, subsurface soil samples will be collected every 10 feet of depth. At seven locations in the Buffer Zone, subsurface soil samples will be collected at the top and bottom of the unsaturated zone. The analytes list for these samples will include explosive compounds and metals. In addition, the 10-foot deep sample from each of these Impact Area locations, and any sample with an FID detection above background, will be analyzed for all target compounds. At borings outside the Impact Zone, subsurface soils will be sampled at 10 foot intervals. The samples will be used for lithologic logging and field screening using a Flame Ionization Detector (FID). A determination will be made in the field based on FID readings whether any of the samples will be submitted for laboratory analysis.

As the study progresses and analytical results are received, additional soil sampling may be conducted. Additional analysis requirements will be determined in consultation with the EPA.

4.1.5 Water Level Measurements

After installation, development, and a stabilization period of at least seven days, the water levels in all new and some existing wells around the training range and Impact Area will be measured using an audible electric water level measuring device. The device is lowered into the well and emits sound that indicates the presence of water. The depth to water shall be measured from the reference mark at the top of the well casing, to an accuracy of 0.01 feet. The depth to water will be recorded in a field notebook (see MMR SOP 1-6, CDM, 1993). These data will be used to generate groundwater contour maps, which will be updated periodically throughout the duration of the well installation program as more data points become available.



DESIGNED ______ DATE DRAWN ______ DATE CHECKED ______ DATE APPROVED ______ DATE	ENGINEERING TECHNOLOGIES ASSOCIATES, INC. ENGINEERS • PLANNERS • SURVEYORS 3458 ELLICOTT CENTER DRIVE SUITE 101 ELLICOTT CITY, MARYLAND 21043	Figure 4-1 Typical Soil Sampling Grid SCALE: CONTRACT NO.: DATE: SHEET:

4.1.6 Groundwater Sampling

Groundwater samples will be collected from each new investigation well and some of the existing IRP and LRWSPAT test wells. These samples will be analyzed for explosive compounds, TAL inorganics, TCL VOCs and TCL SVOCs, phosphorus, nitrate/nitrite, ammonia, TCL pesticides/PCBs, herbicides, ethylene dibromide (EDB), and methyl-tertiary-butyl ether (MTBE).

After a seven-day stabilization period, all investigation wells will be sampled. Prior to sampling, each well shall be purged using the EPA Region I low-flow purge and sampling procedure (see Appendix C). Sample bottles will be filled according to the analytical requirements. All groundwater samples will be analyzed for explosive compounds, phosphorus, nitrate/nitrite, and ammonia, and the TAL inorganic parameters (filtered and unfiltered). Selected groundwater samples will be analyzed for VOCs, SVOCs, pesticides/PCBs, herbicides, EDB, and MTBE. The selection will be based on location downgradient of suspected sources and hydrologic considerations.

The samples for volatile organic analyses will be collected in two 40-ml vials, ensuring no air bubbles are entrained in the sample. The samples will be preserved with hydrochloric acid (HCl) to a pH less than 2. The remaining sample bottles will be filled after the VOC samples are collected. All samples will be collected by allowing water to flow into the container with a minimum of disturbance. For samples requiring preservatives, the preservative will be added to the container before the water. Filtered samples will be filtered through a 0.45-micron filter by attaching the filter to the discharge port of the sampling pump. All samples will be labeled and immediately placed on ice for delivery to the laboratory. A chain of custody and field record will be maintained for all samples (see MMR SOP 1-2, CDM, 1993).

4.1.7 Sample Designations and Identification

For tracking purposes, samples will be designated and identified according to the MMR protocol, using 14 alphanumeric characters. The 14 alphanumeric characters will constitute six information groups:

(i) The first two characters denote a site code, which usually is a number between 01 and 99 assigned to a site at the time of initial information gathering. The site code for the training range and Impact Area will be 71.

(ii) The next two characters denote sample types. The general nomenclature of this code is as follows:

BS: Soil boring sample
BW: Groundwater sample from a boring
GB: Water sample from a geologic boring
MS: Investigation well soil sample
MW: Groundwater sample from a investigation well
QS: Equipment rinsate sample
QT: Trip blanks
QW: Source water sample
WT: Water table sample

(iii) The next three characters represent the horizontal locator, which in this case will be the well numbers. The horizontal locator consists of numbers ranging from 001 up to the total number of wells installed.

(iv) The next three characters represent the vertical location and help distinguish between samples taken from different depths at the same horizontal location. For nested well clusters, these characters will be A, B or C, with A representing the deepest well.

(v) The next two characters denote the event number, and usually reference the chronological event for a specific activity such as the number of rounds for groundwater sampling.

(vi) The last two characters represent the sample modifier in the case of duplicates and matrix spikes.

After an identification number has been assigned to each sample, pertinent information about each sample will be documented in the sample log sheet and field log book, including:

- Sample number;
- Date and time sample collected;
- Well and/or boring identification number;
- Depth of sample;
- Analysis to be performed;
- Sample description;
- pH, temperature, and specific conductivity (for groundwater samples only);
- Name of person collecting the sample; and
- Notes regarding unusual site conditions.

4.1.8 Waste Handling

Investigation-derived waste will be handled according to the modified MMR IRP procedures which are described in Section 5.0 of this document.

4.1.9 Health and Safety Monitoring

A Health and Safety Plan (HASP) has been prepared (see Appendix B). The plan details the health and safety procedures to be followed during all field activities, including the UXO survey phase of the project. The UXO screening will include all sampling areas and access roads to

these areas within the Impact Zone. These surveys will be performed by a qualified UXO specialist following standard Army procedures in consultation with the explosive ordnance detachment.

4.1.10 Hydrogeologic Characterization

Aquifer testing plans will be developed in consultation with the EPA, MADEP, LRWSPAT, and USGS as the study progresses.

4.1.11 Quality Control Samples

The types of Quality Control (QC) samples to be collected during the field work include trip and field blanks, equipment rinsate blanks and duplicates. These items are explained below.

4.1.11.1 Field and Trip Blanks

Field blanks are samples collected from the source of water used for drilling, decontamination and steam cleaning during the investigation. At least one field blank is collected from each source of water used for a given program. Normally, the same source of water is used for steam cleaning and decontamination, so only one field blank is collected. However, if different sources of water are used for these purposes, additional field blanks must be taken.

Trip blanks are 40-ml glass vial samples prepared by a laboratory, transported to the sampling site and returned to the laboratory with VOC samples. Trip blanks are used to detect contamination by VOCs during sample shipping and handling. Trip blanks accompany and are stored and analyzed with VOC samples.

4.1.11.2 Equipment Rinsates

Equipment rinsate samples are collected by passing water through decontaminated sampling equipment. These samples are used to measure the effectiveness of the decontamination process. MMR SOP 2-2 recommends collecting one rinsate for each type of sampling equipment used

4.2.1 Field Screening

Soil samples will be subjected to field headspace screening for volatile organics using a Flame Ionization Detector (FID). Results of this screening will be used to determine worker protection and/or to identify samples for laboratory analysis.

4.2.2 Laboratory Analysis

Laboratory analysis will be conducted using EPA Contract Laboratory Program (CLP) methodologies, except where no CLP method exists. In these cases, the analysis will be done by methods used for similar investigations at MMR or other military installations.

Tables in the QAPP (Appendix A) summarize the analytes list, the Maximum Contaminant Levels (MCLs) and/or soil screening limits as stipulated by the MMR Risk Assessment Handbook, and the typical method detection limits that can be attained by the laboratory.

4.2.3 Data Management and Evaluation

Analytical reports will be reviewed for sample collection, handling, analytical and reporting consistency. The project-specific Quality Assurance/Quality Control (QA/QC) plan is provided in Appendix A.

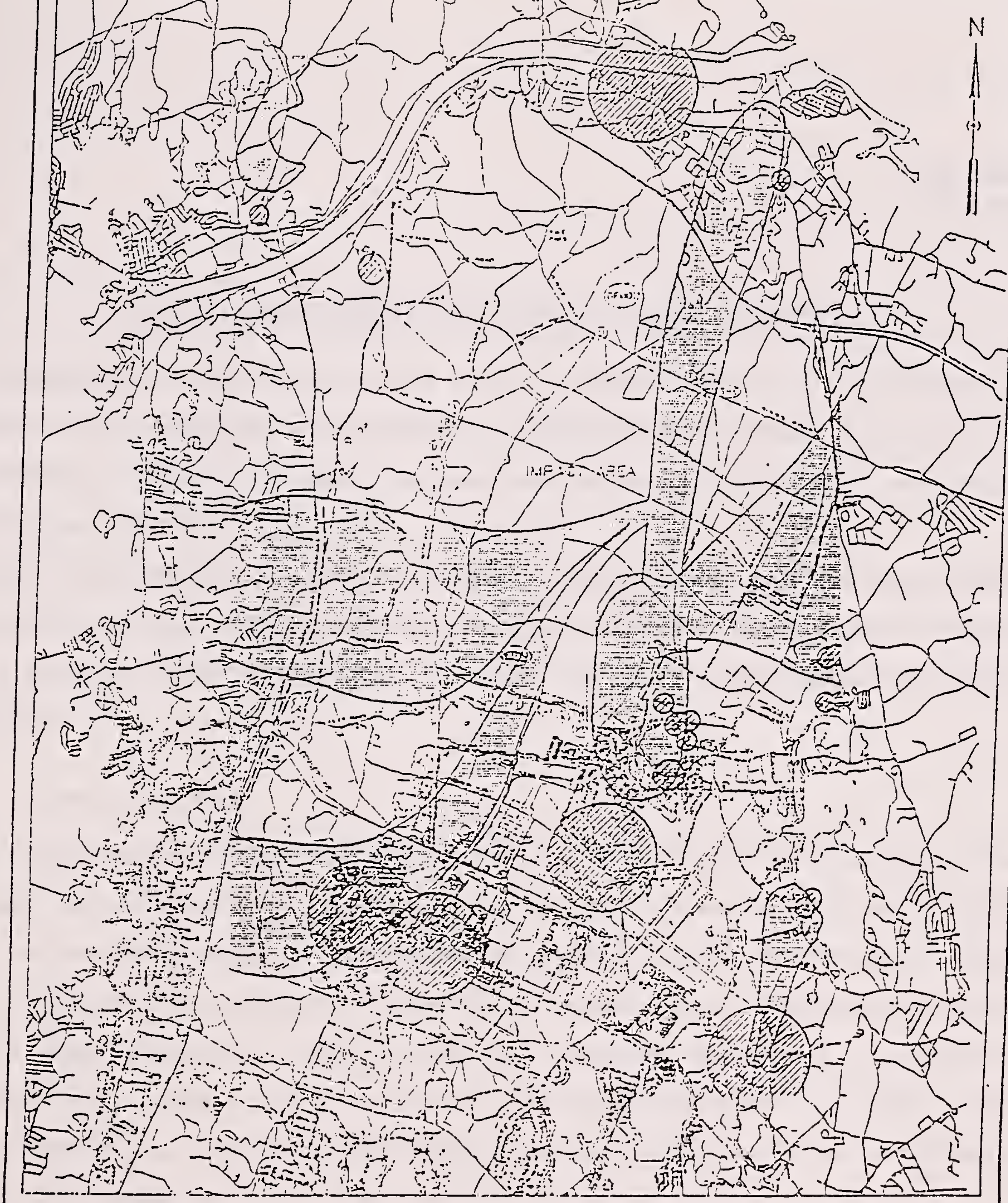
A systematic process to evaluate and validate the data for this project is outlined in the site-specific QA/QC plan. This data validation process will consist of the use of acceptable criteria to provide assurance that the data are adequate for their intended use. The process will involve data editing, screening, checking, auditing, verification, flagging, certification and review. The data review and validation will be conducted independent of the laboratory conducting the analyses.

4.2.4 Well Head Protection Area Review

There are several municipal water supply wells to the south of the training range and Impact Area (Bourne, Falmouth, and Sandwich). There are also water supply exploration efforts taking

place around the training range and Impact Area. The zone of contribution to these wells will be examined and reviewed to determine if the training range and Impact Area falls within the limits of the Zone II well head protection areas of these municipal wells or the water supply test wells being drilled and tested in and around the range and Impact Areas. Figure 4-2 shows the preliminary Zone II areas for the LRWSPAT test wells (Stone and Webster, 1996).

Massachusetts law requires water supply wells to delineate a well head protection area (WHPA). Municipalities are required to enact special zoning ordinances and take other measures to protect groundwater within the WHPA against contamination (MADEP Guidelines and Policies for Public Water Systems, 1991). Each water supply well permitted to pump more than 100,000 gallons per day is required by law to delineate Zone I, Zone II, and Zone III WHPAs. Zone I is the area within a 400-foot radius of the well. Zone II is the area that contributes water to the well under specific, permitted pumping and recharge conditions. Zone III is the watershed that contributes water to the well. The Zone II delineation prepared for the existing and potential municipal wells will be reviewed to verify if they fall within the training range and Impact Area.



NOTE:
ZONE II AREAS HAVE BEEN APPROXIMATED.
SOME ZONE II AND INTERIM WELLHEAD PROTECTION EXTREME BOUNDARIES HAVE NOT BEEN COMPLETELY DEFINED.

1" = 5000'

Source:
Camp Edwards Environmental Protection Office

LEGEND
INSTALLATION BOUNDARY
ZONE II
INTERIM WELLHEAD PROTECTION AREA

FIGURE 4-1

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Zone II Welhead Protection Areas

SCALE | CONTRACT NO. | DATE | SHEET

5.0 DECONTAMINATION AND WASTE DISPOSAL

All equipment and tools will be cleaned before beginning the field work and during well installation and sample collection. All personnel will be protected as outlined in the Health and Safety Plan. This work will generate investigation derived wastes (IDW) that will need proper handling and disposal.

These investigation derived wastes will include drill cuttings from well installation, waste liquids from decontamination activities, well development and purge waters, unused sample bottles and used protective clothing and equipment. These wastes will be handled according to the following protocol.

5.1 Decontamination

The drilling contractor will provide an acceptable rig and support truck equipped with a steam cleaner, water tank, portable wash rack, and other equipment necessary to complete the drilling and well installation program. A decontamination pad for the heavier equipment (such as rigs, augers and rods) and a staging area for supplies will be constructed at a location approved by the MMR Range Management Office. All drill rigs, construction equipment and tools will be cleaned before beginning the field program. All decontamination will take place at the decontamination pad except for reusable sampling equipment, which may be decontaminated at the drilling location.

Decontamination procedures will follow the SOP for environmental investigations at MMR (CDM, 1993) Cleaning of heavy equipment will consist of scraping, brushing, washing with potable water and steam cleaning until exposed surfaces are free of soil residue. All downhole sampling equipment will be steam cleaned and rinsed with deionized water, and air dried. Pumps and tubing used for sampling groundwater during drilling for screening analysis will be decontaminated by circulating potable water in the pump and submersible lines. Pumps used for

normal groundwater sampling will be decontaminated by circulating a Liquinox/water solution through the pump, followed by a deionized water rinse. Tubing will either be dedicated or discarded after each sample.

Reusable sampling equipment will be decontaminated according to the following procedure:

- Remove visible contamination by brushing or wiping with a cloth;
- Wash and scrub with an Liquinox/water solution;
- Rinse with potable water;
- Rinse with deionized water;
- Rinse with methanol; and
- Air dry and wrap equipment in aluminum foil.

Reusable protective clothing and equipment (such as gloves, boots and hard hats) will be decontaminated as follows:

- Wash with an Liquinox/water solution
- Rinse with potable water;
- Rinse with distilled water; and
- Air dry and store in a polyethylene bag to prevent contamination during storage or transport.

5.2 Waste Disposal

The investigation and decontamination process will generate wastes that require proper handling and disposal. The following is an outline of the appropriate handling procedures for each of these waste streams.

5.2.1 Personal Protective Equipment (PPE)

All used PPE will be segregated based on the judgment of the field supervisor as to whether they are hazardous waste or trash. PPE contaminated with hazardous waste will be drummed and stored at the central staging area for proper disposal. PPE not contaminated by hazardous waste will be disposed of as general trash.

5.2.2 Soil

The soil boring and investigation well installation programs will generate soil cuttings. Samples of the soils will be screened for volatile organic compounds by an FID instrument, using the headspace screening method. Soil cuttings will be stockpiled at the surface at each well location and left in place if headspace screening results for discrete samples using an FID are less than 5 ppm above background, and results of explosives analysis on a composite sample using EPA method 8515 and the CRREL colorimetric method indicate levels less than two times local surficial background levels determined from a composite sample. In the event that soil cuttings do not meet these criteria, the IRP SOP for soil classification for disposal will be followed. Soil cuttings that are containerized rather than left on site will be analyzed for VOCs, SVOCs, herbicides, pesticides, and metals after consolidation of like materials, in accordance with IRP SOP. Cuttings to be containerized will be drummed in a plastic-lined, DOT-approved, open-end sealed 55-gallon steel drum. Recycled drums may be used; however, the liner must be new and water tight. For tracking, all drums will be labeled with an identification number, the place of origin (soil boring or well designation) and content. Materials from different borings will not be combined in the same drum, nor will solid and liquid wastes be placed in the same drum.

All drums containing investigation derived soil cuttings will be transported to the central staging area. Disposition will be the responsibility of the Massachusetts Army National Guard (MAARNG).

5.2.3 Water

Drilling water, well development water, and purge water generated at each well location will be treated at the location by passing it through two granular activated carbon canisters in series and discharging the treated water to the ground surface. Water samples will be collected from the discharge port of the first canister at a frequency of one sample for every 2000 gallons of water treated. These samples will be analyzed for explosive chemicals to ensure that no contaminated water is returned to the aquifer.

Decontamination solutions will be containerized in DOT-approved 55-gallon steel drums. These solutions will be tested for RCRA characteristics after consolidation of like materials. Drums will be staged at a designated area, and disposition will be the responsibility of the MAARNG.

6.0 SITE-SPECIFIC QUALITY CONTROL AND HEALTH AND SAFETY PLAN

The field work for this project will be conducted within the guidelines of the MMR Standard Operating Procedures (SOP), Quality Assurance/Quality Control (QA/QC) and the general Health and Safety Plan (HASP). However, these generic plans will be amended through addenda to address site and project specific requirements. Only the addenda are discussed and provided as appendices to this work plan. The original documents are made part of this document by reference.

6.1 Quality Assurance Project Plan

Appendix A is a detailed, project-specific QA/QC plan, which will be an addendum to the original document. It details the QA/QC measures that will ensure that the data quality objectives of this project are met. A systematic data validation process will ensure the data are adequate for their intended application and use.

6.2 Health and Safety Plan

A site-specific health and safety plan is provided in Appendix B. All personnel who work in the field will be required to have completed the 40 hour Occupational Safety and Health Administration (OSHA) Hazardous Waste Site Investigation Training and have current certification. In addition, a baseline and exposure history will be maintained for all personnel through a medical surveillance program. The health and safety officer will maintain and document such records. The anticipated level of worker protection is Level D, but all field personnel will be prepared to upgrade to a modified Level D or Level C. For that purpose, sufficient safety equipment will be maintained on site for all personnel to provide for appropriate

protection as determined by the on-site health and safety officer. At a minimum, the following safety equipment must be available for all personnel on site:

- Safety goggles;
- Hard hats;
- Chemical resistant/Tyvek coveralls;
- Steel-toed work boots;
- Disposable rubber gloves;
- Full-face air purifying respirators; and
- Adequate supplies of GMC-H APR cartridges.

The field supervisor or his designate will conduct a daily safety meeting for each field activity. The supervisor also will be responsible for instituting the necessary supplemental safety procedures.

7.0 PROJECT MANAGEMENT AND SCHEDULE

7.1 Project Management

Figure 7-1 is a chart showing the organizational structure for this project. This project is being conducted under an administrative order from EPA Region I. Therefore, the scope of work and schedule have been developed in consultation with the EPA, who will also feature prominently in the management and approval of the fieldwork and any changes thereto. A brief description of the responsibilities of each entity and key personnel is provided below.

7.1.1 Organizational Structure

The overall responsibility for the program rests with the National Guard Bureau through the interim Project coordinator, Gerard Winters. His responsibility will be to monitor the progress of the program, review and approve all work products and deliverables, monitoring the financial and schedule control, and instituting corrective action, if necessary.

The counterpart is the EPA technical project manager, Ms. Jane Dolan. She will be responsible for ensuring that the quality and schedule of the work meets the requirements of the administrative order; and will also be responsible for controlling the release of information to the public and special interest groups. The EPA project coordinator will also work with the NGB project coordinator and other regulatory agencies to ensure that their needs and opinion are reflected in the conduct of the program.

The primary consultant to the NGB for completion of this program will be Ogden Environmental and Energy Systems (OGDEN). They will be responsible for supervising the fieldwork and

documenting the data and information collected to ensure the technical integrity of the study. By contract, OGDEN will supervise several subcontractors who will provide specialty expertise to various tasks of the program. The OGDEN project Manager will be Mr. Marc Grant. Mr. Grant will work directly with the NGB project coordinator, and will be responsible for project staffing and direct management of all staff and subcontractor assignments to the project. In this role, the OGDEN project manager will be responsible for ensuring that the NGB and EPA project coordinators are kept informed of the technical and schedule progress of the project.

The OGDEN Field Program Manager will be Mr. John Rice, who will be responsible for executing investigation activities. The OGDEN Assistant Field Program Manager, Mr. Sam Farnsworth, will also be on-site during field activities. The OGDEN laboratory coordinator will be Ms. Elizabeth Wessling, who will be responsible for data validation, data management, and laboratory oversight. Other key Ogden personnel will be identified to EPA as needed during the performance of field investigations.

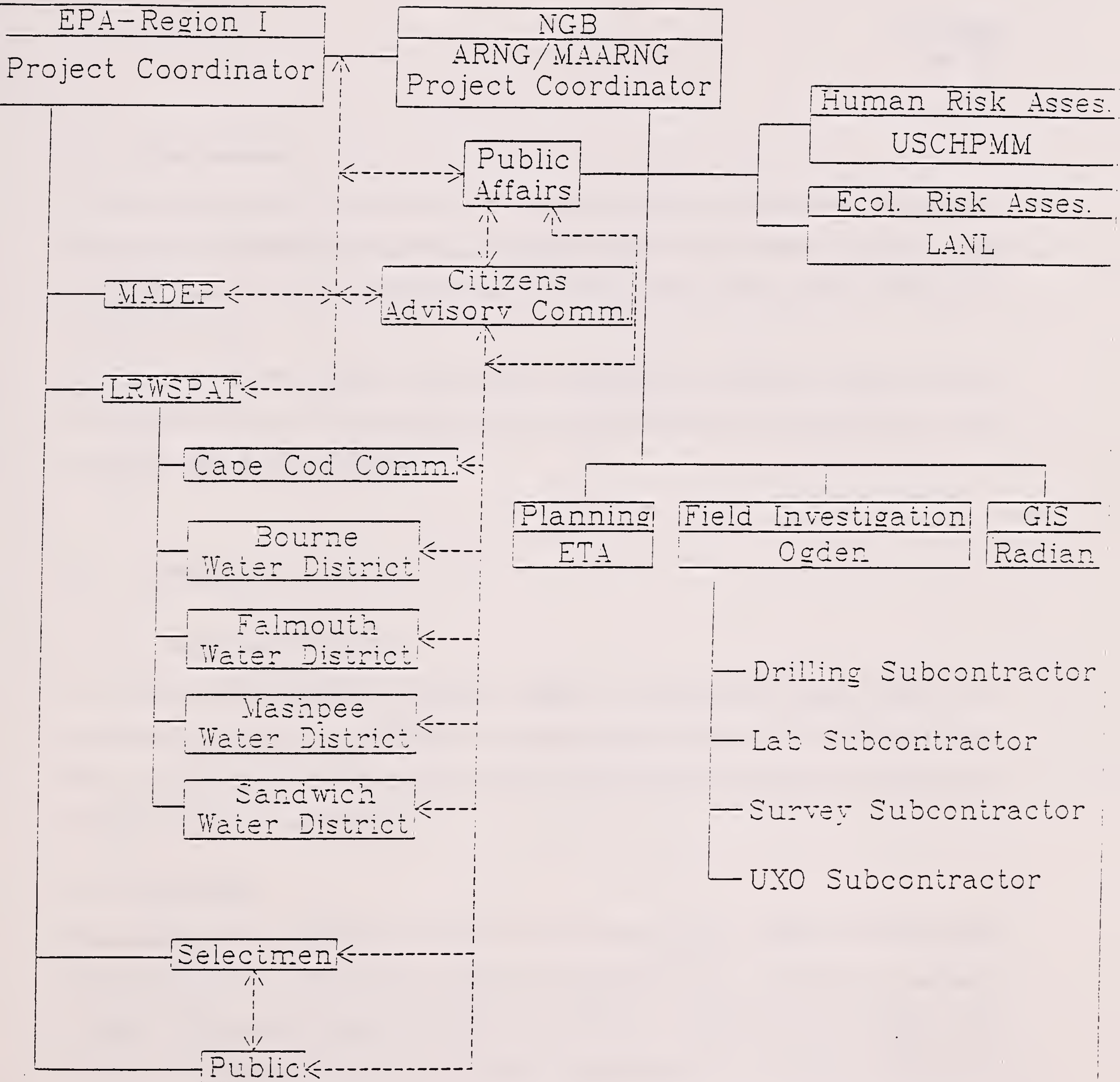

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Figure 7-1
Organizational Chart

7.1.2 Subcontractors

OGDEN will subcontract with some specialty services providers to facilitate the completion of this program. In putting the team together, OGDEN will select team members to provide enough flexibility, technical know-how and experience with the specifics of the project to ensure quality service to the study.

Particular attention will be paid to the specialty functions of the program, so that the selected team members have proven experience and strong staff capabilities in the specialty areas of the project for which they were chosen.

7.2 Schedule

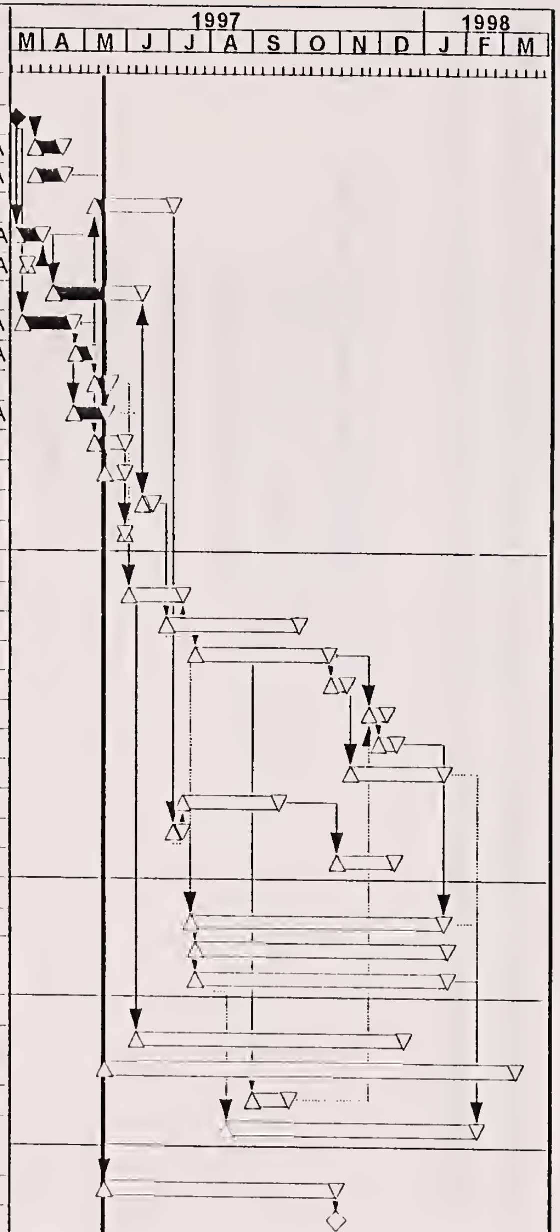
7.2.1 Overall Project Schedule

The overall project schedule is shown in Figure 7-2. The proposed project schedule was developed according to the requirements of the administrative order, and in consultation with the EPA. Any scheduling problems will be resolved at the project coordination level between the NGB and EPA project coordinators.

7.2.2 Deliverables

The primary project deliverable will be the site characterization report. OGDEN will prepare and submit this report as a draft report, a draft final and final report. The report will include a summary of the methodologies and activities conducted, a summary of the results of the literature search and review, and an evaluation and interpretation of the data collected. The conclusions drawn from the study and the inferences made from the data will be included; and recommendations made as to the follow on investigation, if necessary.

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
1	Planning			
005	Submit Workplan for Public Comment	0	14MAR97A	
009	UXO Survey Bid Preparation	15	26MAR97A	15APR97A
010	Drilling/Laboratory Bid Preparation	15	27MAR97A	16APR97A
015	Archive Search	35	09MAY97A	03JUL97
020	Public Comment Period	12	14MAR97A	31MAR97A
023	Public Meeting	1	20MAR97A	20MAR97A
024	NGB/Ogden Prepare Scope of Work	20	09APR97A	12JUN97
025	EPA Comment/Approval/Disapproval	2	17MAR97A	22APR97A
026	NGB/Ogden Prepare Interim SOW	10	24APR97A	08MAY97A
027	Ogden Arrange UXO Subcontract	5	09MAY97A	20MAY97
030	Revise Workplan	10	23APR97A	16MAY97A
035	Mobilize for Field Investigations	10	09MAY97A	29MAY97
037	Ogden Finalize Drilling/Lab Bids	10	16MAY97	29MAY97
038	Ogden Arrange Drilling/Lab Subs	5	13JUN97	19JUN97
040	Investigation Kickoff Meeting	1	30MAY97	30MAY97
2	Field Investigations			
050	UXO Survey	30	02JUN97	11JUL97
100	Monitoring Well Installations	70	30JUN97	03OCT97
105	Well Development/Sampling	70	21JUL97	24OCT97
120	Slug Testing	10	27OCT97	07NOV97
130	Additional Well Installations	10	24NOV97	05DEC97
135	Additional Well Develop/Sample	10	01DEC97	12DEC97
150	Synoptic Water Table Measurements	50	10NOV97	16JAN98
200	Soil Sampling	50	11JUL97	18SEP97
210	Surface Water & Sediment Sampling	5	04JUL97	10JUL97
220	Additional Soil Sampling	30	31OCT97	11DEC97
3	Data Evaluation			
300	Laboratory Analysis & Data Mngmnt.	132	17JUL97	16JAN98
330	Evaluation of Response Actions	132	21JUL97	20JAN98
340	Risk Assessment	132	21JUL97	20JAN98
4	Reports and Meetings			
501	Project Review Meetings	140	09JUN97	19DEC97
550	Monthly Progress Reports	213	16MAY97	10MAR98
560	Interim Results Report	20	01SEP97	26SEP97
600	Completion of Work Report	130	13AUG97	10FEB98
5	Pollution Prevention			
400	Initial Pollution Prevention Activities	120	16MAY97	30OCT97
450	Start Continuing PP Activities	0	31OCT97*	



Early Bar
Progress Bar

National Guard Bureau
MMR Groundwater Quality Study
Figure 7-2. Schedule as of 5/16/97

8.0 RECORD KEEPING AND REPORTING

8.1 Record Keeping

All field activities will be recorded in bound notebooks with sequentially numbered pages or on field log forms. At a minimum, the following information will be entered in the field notebooks or logs:

(i) Surface/Sediment Sampling Data

- Sample location designations
- Depth of sample location
- Visual classification of soils
- Date and time of collection
- Type of container
- FID reading
- Date of shipment to laboratory
- Sampler's name
- Notes regarding unusual conditions

(ii) Subsurface Soil Sampling

- Soil boring designation
- Visual classification of soils (unified system)
- Depth to groundwater
- Date of boring
- Interval/depth of sample
- Date and time of collection
- Field weather conditions

- Analysis required
- Date of shipment to laboratory
- Sampling method
- Sampler's name
- Notes regarding unusual conditions

(iii) Groundwater Investigation well data

- Investigation well designation
- Surface coordinates, top of casing elevation, depth of borehole and depth of well
- Visual soil classification
- Depth to groundwater
- Date of installation
- Boring and well completion logs
- Well development logs
- Field weather conditions
- Notes regarding unusual conditions

(iv) Groundwater Level Measurements

- Well designation
- Date and time of measurement
- Well depth
- Static water elevation
- Type of measuring equipment used
- Technician's name
- Notes regarding unusual conditions

(v) Groundwater Sample Data

- Well designation
- Well depth and static water level
- Well volume and required purge volume
- Type of container and preservatives
- Types and makes of sampling equipment
- Monitoring equipment readings
- Date and time of collection
- Analysis required
- Date of shipment to laboratory
- Sampler's name
- Notes regarding unusual conditions

All entries in the field notebook and the field logs will be made in indelible black ink. Corrections will be made by drawing a single line through the error and initialing and dating the correction. Individuals making entries will sign and date the bottom of each page of the notebook. All field log books will be legible.

8.2 Reporting

Upon completion of sample collection and analysis, the results of field observations and laboratory analysis will be summarized in a draft report. This report will consist of a summary of the data, field procedures used and the inferences drawn from the data to identify probable sources, and current status of groundwater quality. It will also recommend the next step for characterization of the site.

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